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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 76.
B. T. GALLOWAY, *Chief of Bureau.*

COPPER AS AN ALGICIDE AND DISINFECTANT IN WATER SUPPLIES.

BY

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VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL
INVESTIGATIONS.

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BUREAU OF PLANT INDUSTRY.

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[a] Detailed to the Bureau of Forestry.
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[d] Detailed to Bureau of Chemistry.
[e] Detailed from Bureau of Chemistry.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 15, 1905.

Sir: I have the honor to transmit herewith a paper entitled "Copper as an Algicide and Disinfectant in Water Supplies," and to recommend that it be published as Bulletin No. 76 of the series of this Bureau.

This paper was prepared by George T. Moore, in charge of the Laboratory of Plant Physiology, and Karl F. Kellerman, Assistant in Physiology, in the Office of Vegetable Pathological and Physiological Investigations, and was submitted by the Pathologist and Physiologist with a view to publication. It is supplementary to Bulletin No. 64, "A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies," and will be of interest and value to all who have to deal with the problem of preventing algal and bacterial contamination of water supplies.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Investigations undertaken by this Office with a view to finding some cheap and practical method of preventing or removing algal and bacterial contaminations from water supplies have demonstrated the peculiar value of copper as an agent for this purpose. The possibilities in the use of this salt are briefly outlined in a previous bulletin (No. 64) entitled "A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies."

During the summer of 1904 many lakes and reservoirs were treated under the direct supervision of representatives of the Laboratory of Plant Physiology, and it has become desirable to present the data gained in the season's experience, together with definite recommendations in regard to the methods of procedure, so that those having to deal with the question of contaminated water may do so to the best advantage.

With reference to the occasional objection offered to the use of copper as an algicide and disinfectant, it ought to be amply sufficient to state that a careful study of all the leading authorities on the subject fails to reveal any argument or evidence which can be adduced in opposition to the use of copper for this purpose. Authorities everywhere unite in defending the use of copper as a means of destroying polluting organisms in water, and agree that it can be used with impunity as advised by the authors.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF VEGETABLE PATHOLOGICAL
AND PHYSIOLOGICAL INVESTIGATIONS,
Washington, D. C., March 14, 1905.

CONTENTS.

Page.
Introduction 9
Difference in toxicity of copper sulphate in laboratory and field conditions 9
Effect of copper sulphate upon fish 11
Conditions determining the proper quantity of copper sulphate for eradicating algæ 12
Appearance of resistant forms of algæ in reservoirs previously treated 12
Odor and taste due to large numbers of algæ killed 13
Reports from various cities and towns upon the effect of treatment 13
    Baltimore, Md 14
    Bond Hill, Cincinnati, Ohio 15
    Butte, Mont 15
    Cambridge, N. Y 17
    Elmira, N. Y 18
    Fieldhome, N. Y 19
    Glencove, Long Island, N. Y 19
    Greenwich, Conn 20
    Hanover, N. H 20
    Hanover, Pa 22
    Ivorydale, Ohio 22
    Johnson Creek, Wis 22
    Middletown, N. Y 22
    Millersburg, Pa 25
    Moncton, New Brunswick 25
    New York, N. Y 26
    Newtown, Pa 26
    Oberlin, Ohio 27
    Passaic, N. J 28
    Port Deposit, Md 28
    Rhinebeck, N. Y 28
    Scarboro, N. Y 28
    Springfield, Ill 29
    Waltham, Mass 29
    Water Mill, Long Island, N. Y 29
    Wellsboro, Pa 30
    Winchester, Ky 30
    Winnebago City, Minn 31
Necessity for determining the polluting organism 31
Troublesome forms and their identification 32
    The Sedgwick-Rafter method of quantitative determination 32
    Key for identifying algæ 35
Method of applying copper sulphate 38
Sterilization of bacteria-polluted water by means of copper sulphate 38
Sterilization of the water supplies at Columbus, Ohio, and Albuquerque, N. Mex 39

Page.

Sterilization of water by means of metallic copper 40
Copper in the disposal of sewage 43
Copper supplementing the use of filters 43
Copper treatment and filtration at Anderson, Ind 44
Objections to the use of copper 48
Opinions of toxicologists upon the effect of copper 48
Medicinal use of copper 51
Conclusion 55
Summary 55

COPPER AS AN ALGICIDE AND DISINFECTANT IN WATER SUPPLIES.

INTRODUCTION.

At the time of publication of the results of the experimental use of copper sulphate as an algicide and disinfectant in polluted water,[a] definite recommendations concerning the proposed method of treatment were avoided. This was done both to check those who through ignorance or excess of zeal might be led to unnecessary or extravagant applications of the treatment and to gain the additional information of a season's experience by maintaining supervision over treated supplies. The work can no longer be considered in an experimental stage, however, and the present need is not an exposition or explanation of the method but a discussion of actual experience, which, by setting forth the conditions presented, the difficulties encountered, and the success attained, may serve as a guide to the water engineer and to those who find it necessary to use copper in dealing with contaminated supplies. An attempt is therefore made to arrange and correlate the results of laboratory work and practical applications of the method, with a view to facilitating the comprehension of the various ideas involved in the abundant results that the work has yielded. Moreover, it is apparent that the prejudice against using copper in drinking water is still great in many quarters, and some pains have been taken to ascertain whether there exist sufficient grounds for this hostility.

DIFFERENCE IN TOXICITY OF COPPER SULPHATE IN LABORATORY AND FIELD CONDITIONS.

The treating of various reservoirs has brought to light an interesting fact.

The concentration necessary to kill algæ in the laboratory is from five to twenty times as great as that necessary to destroy the same species in its natural habitat. The reason for this is difficult to demonstrate. It is not due to difference of light and temperature, nor to the greater proportion of the treated water to the mass of algæ so often found in reservoirs. The most probable explanation is that under normal conditions the rapid growth of the organism is favored, with a consequent maintenance of the highest degree of sensitiveness to adverse conditions. When algæ are brought into the laboratory, the change in environment and the injury from handling allows only the more resistant individuals to persist, and the forms developing from these are, therefore, harder to destroy than are those of the same species growing in nature.

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[a] Bulletin 64, Bureau of Plant Industry.

In view of this fact the quantities of copper sulphate which are required to destroy the different polluting forms are much less than those formerly considered necessary. Many of the concentrations in the following revised table have been obtained by actual use in reservoirs under natural conditions. The remainder have been determined by analogy, and only on theoretical grounds can they be presumed to be correct.

It will be seen that there is absolutely no possibility of correlating the effects of copper upon related forms with the idea of formulating a rule for general use. Even species of the same genus often show a greater variation in their susceptibility to copper than is found in widely separated genera, and the necessity of knowing the specific form causing the difficulty becomes more and more evident as experience with the effect of copper upon algæ is accumulated.

Number of parts of water to one part of copper sulphate in dilutions recommended for destroying different forms of algæ.

[Water of average hardness, and at a temperature of about 15° C. (59° F).][a]

Aphanizomenon	5,000,000	Microcystis	1,000,000
Anabaena circinalis	10,000,000	Navicula	15,000,000
Anabaena flos-aquae	10,000,000	Nitella	10,000,000
Asterionella	8,000,000	Oscillatoria	5,000,000
Beggiatoa	100,000	Palmella	500,000
Cladophora	1,000,000	Pandorina	100,000
Chlamydomonas	1,000,000	Peridinium	450,000
Clathrocystis	8,000,000	Raphidium	300,000
Closterium	6,000,000	Scenedesmus	1,000,000
Coelosphaerium	3,000,000	Spirogyra	25,000,000
Conferva bombycinum	3,000,000	Stigeoclonium	3,000,000
Crenothrix	1,000,000	Stephanodiscus	250,000
Desmidium	450,000	Synedra	600,000
Draparnaldia	3,000,000	Synura	3,000,000
Eudorina	100,000	Tabellaria	600,000
Euglena	1,500,000	Ulothrix	5,000,000
Fragilaria	4,000,000	Uroglena	20,000,000
Glenodinium	2,000,000	Volvox	4,000,000
Hydrodictyon	10,000,000	Zygnema	2,000,000
Mallomonas	500,000		

SALT WATER FORMS.

Cladophora	5,000,000	Ulva	5,000,000
Enteromorpha	10,000,000		

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[a] See page 12.

EFFECT OF COPPER SULPHATE UPON FISH.

The effect of copper sulphate upon different species of fish demands more attention than was formerly supposed. The treating of a small trout pond in Massachusetts resulted disastrously to about 40 per cent of the 8-inch trout with which the pond was stocked, and emphasized the fact that all game fish are not equally resistant to the effect of copper. A series of investigations[a] has shown that the brook trout is more sensitive than any other fish yet tested. In some cases 1 part of copper sulphate to 7,000,000 parts of water is the maximum strength that can be endured by trout under 5 inches in length. Larger ones, as a rule, will endure but a slightly stronger solution, though the treatment of one reservoir was reported in which a solution of 1 to 1,000,000 was used without injury to trout or other fishes. Here, however, the immunity was probably due to the rapid precipitation of the copper by organic matter or alkalis[b] and not to the resistant condition of the fish. Reference to the reports of reservoirs treated, notably those of Butte, Mont.,[c] Cambridge, N. J.,[d] and Hanover, N. H.,[e] shows that fish are uninjured at concentrations ordinarily used and their presence is no obstacle to successful treatment.

Below are given the maximum amounts of copper sulphate which, judging from a very limited number of experiments, should be used in water containing fish of certain species. It is hoped that work planned in connection with the Bureau of Fisheries will make possible a fuller report upon this phase of the subject.

Number of parts of water to one part of copper sulphate in dilutions which will not injure fish of certain species.

Trout	7,000,000	Catfish	2,500,000
Goldfish	2,000,000	Suckers	3,000,000
Sunfish	750,000	Black bass	500,000
Perch	1,500,000	Carp	3,000,000

Experiments of the United States Commission of Fish and Fisheries[f] show that 1 part of copper sulphate to 582,000 parts of water will kill quinnat salmon in a few hours; this suggests that this fish is very sensitive, probably being killed at concentrations between those fatal for trout and those fatal for carp.

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[a] At Coldspring Harbor, N. Y., through the courtesy of the Bureau of Fisheries and the New York Forest, Fish, and Game Commission.

[b] In water containing carbonates, if the amount of dissolved carbon dioxid is very low, the basic carbonate of copper formed may be considered insoluble; if, however, the water should contain a fair amount of carbon dioxid it would bring the copper carbonate at least partially into solution. In general, it will be safe to treat a lake with a concentration beyond that which the fish in it could endure in pure water, and the concentration may increase with the quantity of organic matter present.

[c] Page 15.

[d] Page 17.

[e] Page 20.

[f] Report of the Commission of Fish and Fisheries, Part XXVII, p. 118, 1901.

CONDITIONS DETERMINING THE PROPER QUANTITY OF COPPER SULPHATE FOR ERADICATING ALGÆ.

The importance of knowing the temperature of the contaminated water is second only to the necessity of knowing the organism present. With increase in temperature the toxicity of a given dilution increases, and vice versa. Assuming that 15° C. (59° F.) is the average temperature of reservoirs during the seasons when treatment is demanded, the quantity of copper should be increased or decreased approximately 2.5 per cent for each degree below or above 15° C. It is probable that the influence of temperature could be better expressed by geometrical than by arithmetical progression, but the accurate determination of this point can be made only after experiments have been recorded in various localities under different conditions for a number of years.

Similar scales should be arranged for the organic content and the temporary hardness of the water. With the limited data at hand it is impracticable to determine these figures, but an increase of 2 per cent in the quantity of copper for each part per 100,000 of organic matter and an increase of 0.5 to 5 per cent in the proportion of copper for each part per 100,000 of temporary hardness will possibly be found correct. The proper variation in the increase due to hardness will depend upon the amount of dissolved carbon dioxid; if very small, 5 per cent increase is desirable; if large, 0.5 per cent is sufficient.

APPEARANCE OF RESISTANT FORMS OF ALGÆ IN RESERVOIRS PREVIOUSLY TREATED.

Since adding copper to a reservoir destroys only the polluting organisms then present in the water, it is possible that other forms, the resting spores of which are buried in the mud, may develop after treatment and occasion a second pollution. There is thus the probability that some reservoirs will be cleansed of Anabaena or Oscillatoria or some such polluting species only to allow a subsequent development of forms more or less resistant to copper, such as some of the desmids. It is improbable that these organisms, or any of the algæ, in fact, could develop rapidly enough to be the cause of serious complaint and still remain resistant to such concentrations of copper as could be safely used. At the worst the presence of these forms is certainly to be preferred to that of organisms producing odor and taste, and fortunately experience has shown that the latter succumb so readily to the copper treatment that their destruction has offered no great difficulty.

ODOR AND TASTE DUE TO LARGE NUMBERS OF ALGÆ KILLED.

A certain proportion of the algæ killed by copper treatment floats to the surface and disintegrates there, but the greater part apparently sinks to the bottom, and it may sometimes be necessary to flush out this lower stratum of water and decaying organic matter. In case large masses accumulate upon the surface, as may occur in a reservoir very badly infested with Anabaena, it is desirable to skim off as much of this mass as possible. By this means the water can be rendered fit for use in the minimum length of time, although such procedure would be required only in a reservoir in which the polluting algæ had developed until the water was in very bad condition, and this should never be allowed to happen. The algologist of a water company should watch for the appearance of polluting forms, and advise treatment as soon as signs of increase are unmistakable.

The only undesirable effect of treating a water supply which is contaminated with an alga producing odor and taste is that during the first few days after treatment the odor and taste may increase. In a municipal supply in which the service mains are fed from the bottom of the reservoir this increase may be very marked and occasion additional complaint among the consumers. The trouble is, of course, caused by the simultaneous disintegration of large numbers of algæ and the consequent liberation of comparatively large quantities of the volatile oils to which the odor and taste are due.

REPORTS FROM VARIOUS CITIES AND TOWNS UPON THE EFFECT OF TREATMENT.

The copper method has been used throughout the year during different seasons and under varying conditions, and the work has fully demonstrated the value of this metal for destroying the contaminating algæ in reservoirs of drinking water, as well as in park lakes, fish ponds, and similar small bodies of water which must be kept in good condition. The first reservoir so treated was that of the Winchester Water Company, at Winchester, Ky. The organism polluting the water was *Anabaena circinalis*, and its destruction, as described in a previous publication,[a] seems to have been most thorough. But one treatment was made last year, and no complaint of the quality of the water has arisen since the summer of 1903. Experience only can determine how often a reservoir will need treatment, but the results at Winchester and with other large bodies of water in which none of the blue-green algæ, formerly so abundant, have appeared since the original treatment over a year ago, and this in spite of a season unusually favorable for their development, suggest that applications made at long intervals will suffice to prevent a recurrence of the contamination.

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[a] Bulletin No. 64, Bureau of Plant Industry, p. 27.

In Massachusetts some abandoned reservoirs and ponds unfit for supplying water for drinking purposes have been treated, but as this work was done in cooperation with the State board of health, which has decided that further experiments are necessary to determine the final condition of the copper used in treating before advising the general use of this method, it seems best to defer publication of whatever results have been obtained until the board of health is in a position to make a definite statement.

Probably the most convenient form in which to group the year's results is an alphabetical list of some of the cities and towns in which such work has been done, and a résumé of the cases when necessary. It is impossible for various reasons to include in this list of all of the places where copper sulphate has been successfully used for the destruction of algæ.

BALTIMORE, MD.

Late in June Mr. Alfred M. Quick, engineer of the water department of Baltimore, reported some trouble due to algæ. The following extract from his letter shows the character of the pollution:

> For some time past this department has been in receipt of a great many complaints from consumers of the bad condition of the water. Ice makers were most interested, as it is necessary that water used in making ice should be perfectly clear. They complained that the bad condition generally occurred after long spells of rainy weather, and generally at the change of season—from spring to summer; also that it seemed to be practically impossible to eliminate discoloration. (June 25, 1904.)

Lakes Clifton and Montebello were visited on June 28 and were found to be badly infested with *Anabaena circinalis;* the organisms were unusually perfect spirals, and, estimated roughly, would count about 10,000 to 50,000 per cubic centimeter. On account of the pressure of municipal affairs treatment was not made until July 29, after which Mr. Quick wrote as follows:

> I have completed the experiment of treating the water in Lake Clifton with copper sulphate to eliminate the algæ, and I am glad to say that the result has been an unqualified success.
>
> Before the lake was treated it had a cloudy, greenish color. Immediately after treatment it had a steely, bluish color, and when the lake was turned into service again, one hundred and twenty hours after the application of the sulphate, it had a clear white color.
>
> Notwithstanding the small amount of sulphate used in proportion to the volume of water treated, all of the particular algæ which cause discoloration and odor, which I believe are the cyanophyceæ, were eliminated in forty-eight hours, and practically all of the various other kinds of algæ were eliminated in one hundred and twenty hours.
>
> As for any deleterious effect from the use of the sulphate, the city chemist reported to me that an analysis of 500 c.c. of the water one hundred and twenty hours after treatment showed no traces of copper. (August 9, 1904.)

Later Lake Montebello was treated, and reports of the results in both reservoirs were sent to this laboratory, together with a tabulated count[a] of the organisms before and after treatment. These sheets showed only a moderate reduction of algæ and a total number of organisms per cubic centimeter before treatment so small that it could never have been responsible for the complaints of the consumers, nor could these few organisms have produced the changes in color noted in Mr. Quick's letter. No Anabaena filaments were listed, though it is known that they were present in great abundance a month or so earlier when the examination was made by the Laboratory of Plant Physiology, and there is nothing in the conditions obtaining in the reservoirs before treatment that would explain their absence. It seems probable, therefore, that the samples examined by the city bacteriologist had been agitated sufficiently to break up the delicate Anabaena, or that on account of standing too long before examination this alga had disintegrated. The discrepancies between the tabular reports and the correspondence with this laboratory as they appear in the account of this work are undoubtedly due to this fact. The same explanation seems the most plausible one to apply to the fol-following letter from Mr. Quick, dated September 10, 1904, as the number and character of organisms mentioned by him were too small to produce any deleterious effect.

> I am hardly in a position to state just what form of microscopical vegetable organism gives us the most trouble, but I have no doubt that the table will enable you to form some idea as to this. These organisms are not now giving us any trouble, but from the result of examinations made of samples of water taken a few days ago from Clifton and Montebello (which show the organisms now present to be about the same number or more than before treatment), it is likely that we shall have the same cause for complaint again in the near future.

BOND HILL, CINCINNATI, OHIO.

The following letter regarding the use of copper in a pond containing fish speaks for itself. The algæ, however, disappeared.

> After weighing out a half ounce of copper sulphate, the quantity looked so small I added a little to it and dragged it through the water on a pole. Sunday morning (July 24) is when I treated it. Yesterday the water looked very bad, and the fish that have disappeared from sight all the summer were swimming on top and seemed in distress. (July 26, 1904.)

BUTTE, MONT.

The following extracts from letters and the report of Mr. Eugene Carroll, superintendent of the Butte Water Company, give details of the treatment made during the summer of 1904.

> This company has a large reservoir containing about 180,000,000 gallons, that was completed in 1896. Notwithstanding the fact that we were particularly careful in cleaning the bottom and removing the soil, we have had continual trouble every year from the Anabaena.

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[a] Published in the Engineering News, 52 : 283.

The pest begins to show about the middle of June, and about the 1st of July the water is unfit for use on account of the odor and taste. It remains in a condition unfit for domestic use until about December, when the freezing weather purifies the water and we are able to use it during the winter. (June 3, 1904.)

It has been our custom for the past three years to cut this reservoir out entirely from our water supply from the time of the appearance of the taste and smell until the water purifies in the winter, so we can cut it out for any length of time necessary for the experiment.

Our reservoir is full of native trout, and while I do not care particularly about the fish, yet a solution strong enough to kill the fish might give us more trouble with the dead fish than we would have with the Anabaena.

As to the expense, that is a very small item to us, as we have spent nearly a million dollars in bringing in another water supply, largely on account of the spoiling of the water in our main reservoir. (June 14, 1904.)

(*Report after treatment.*) The Basin Creek Reservoir has two forks, one extending about three-fourths of a mile in a southerly direction and the other about one-half mile in a southwesterly direction. Distribution of the copper sulphate was started at 2 p. m. on July 7, using three boats. One boat distributed in the southern fork, another in the southwestern fork, and the third boat in the main body of the reservoir in front of the dam. The quantity used was 1 pound of copper sulphate to each million gallons of water, thus requiring 180 pounds of sulphate. One boat distributed 40 pounds in one hour in the short arm; the second boat distributed 60 pounds in one hour and ten minutes in the main body of the reservoir around the dam, and the third boat distributed 80 pounds in the long arm of the reservoir in one hour and fifty minutes. In each boat two men were used, one to row and one to hold the gunny sack containing the sulphate over the stern of the boat.

There was a heavy wind blowing downstream, which made it extremely difficult to row, but the boats were kept in continual motion from the time the copper sulphate was dropped into the water until it had entirely dissolved.

During the first ten minutes of the distribution of the sulphate nothing peculiar could be noticed in the water, but after fifteen minutes fine light-green threads began to float in it, growing steadily in number and extension until in about thirty-five minutes after starting there had formed a yellowish-green scum over the entire surface of the reservoir. The phenomenon was similar to the formation of a very flocculent precipitate.

In about two hours the scum assumed a dark-green color, the borders turning slightly brown. At that time a sample of the water was taken and carefully examined and small traces of copper were shown by the experiment. Samples of the scum were also examined and found to contain 11¼ per cent of metallic copper, showing that a large amount of the copper was taken up by the Anabaena and other organisms, and thereby removed from the water.

During the first twenty-four hours the water in the reservoir exhaled a more pronounced and disagreeable grassy odor than before treatment. Its color at the end of the first twenty-four hours was a decidedly dirty green, with comparatively very little scum floating on the surface, and upon testing 1,000 c. c. of the water for copper at this time, a very faint reaction was obtained. The sulphates in the water were slightly higher and the odor was considerably less.

At the end of the second and third days very slight changes were noticed in the color and taste of the top water, but it was greatly improved in taste, color, and smell below 20 feet in depth.

At the end of the fourth day a continued improvement was noticed in the taste, color, and odor, and at the end of the fifth day there was a very decided change for the better in color—the water assuming a natural color and only a slight odor and taste being noticeable on the surface. At 20 feet below the surface at the end of the fifth day, the water was tasteless and odorless, and of a bright natural color. Very slight changes for the better were noticed on the seventh, eighth, and ninth days, and on the tenth day the water apparently had assumed its normal condition.

Microscopical examinations of the water, however, during this period, as shown in the appended tables, revealed the fact that there were a few spores of the Anabaena left in the water and that the Asterionella had begun to increase again.

Owing to these conditions, it was deemed advisable to give the reservoir a second treatment with the copper sulphate, and on the morning of July 19, twelve days after the first treatment, a second treatment was given in exactly the same manner and with the same quantity as the first treatment.

After the second treatment, very little change was noticed in the water on the surface of the reservoir, and hardly any scum formed. Twenty-four hours after the second treatment, the water showed a very decided improvement in color, with absolutely no taste or odor. On the third day after the second treatment, as shown by the analyses in the tables, the water was in an absolutely normal condition and entirely free of the vegetable organisms which had given us so much trouble in the past.

During the process of these treatments, the reservoir was entirely cut out from the city supply and no flow through it was permitted, the overflow being closed and the water allowed to rise slowly. With the exception of occasionally opening the overflow to remove the scum which had blown down against the dam and an occasional opening of the blow-off pipe, there was no current running through the reservoir during the period.

On Sunday, July 24, the water in the reservoir being absolutely pure for the first time in ten years during the month of July, it was turned on to the city mains.

The cost of the treatment of the reservoir, exclusive of the superintendent and bacteriologist, who directed the operations, was as follows:

360 pounds copper sulphate, at 9½ cents per pound	$34.20
6 laborers, four hours each, at 30 cents per hour	7.30
Total cost	41.50

Equivalent to 23 cents per million gallons.

This expense would be cut down were another treatment made, as only one man to a boat is really necessary.

Late in the summer Asterionella again began to appear in considerable numbers. The increase, however, has not been sufficient to demand further treatment this year.

I will continue to keep a close record of the condition of the water in this reservoir, and think very likely it will be advisable to give it a treatment early next summer.

There is no taste or odor whatever to the water, and we have had no trouble with that supply since the treatment. (December 1, 1904.)

CAMBRIDGE, N. Y.

It was impossible to obtain a sample of the organisms causing the trouble at Cambridge, N. Y., but from the description it seems most probable that it was Anabaena. The following letter from Mr. C. T. Hawley, secretary and treasurer of the Cambridge Water Company, sufficiently explains the situation:

The village of Cambridge is supplied with water from two reservoirs, which were built in 1886. One, the "Lower" reservoir, is supplied from springs, and the other, or "Upper" reservoir, is supplied from a small stream and by water pumped from the "Lower" reservoir. In the "Lower" reservoir there has always been a considerable growth of algæ, but there has never been any taste or odor imparted to the water until last fall. Prior to that the algæ has appeared to "ripen," float to the surface, and blow ashore, where it would be raked up and removed. Last year it sank to the bottom, and soon after the "fishy" odor became very offensive. The reservoir was then emptied, cleaned thoroughly, and refilled. In a short time, however, the taste and odor again became noticeable, and there was more or less trouble until June 9 last, when, having procured one of the bulletins issued by the Department of Agriculture, we used the copper sulphate. The effect was evident in twenty minutes to a half an hour in a decided change in color and appearance of the algæ growth. In twenty-four hours the taste and odor had disappeared and the algæ looked dead, having lost its green color. In a few days the algæ had entirely disappeared, and there has been no trouble since, though there is a slight growth just beginning to show in detached patches within a few days. The reservoir contains about 1,250,000 gallons and we used 10 pounds of sulphate of copper. This did not affect the native trout which are in the reservoir. No water was pumped from the reservoir for several days after the sulphate was used, but the outlet gate was closed and the flow from the springs raised the level of the water in the reservoir and reduced the strength of the dose; nevertheless when the water in the reservoir was emptied into the channel which conveys the overflow to the Battenkill, it cleaned out a heavy growth of algæ from that channel for its full length, about half a mile. If the present growth continues, we shall try the sulphate again this fall, using, however, a less quantity of it, as it is evident from the cleaning of the channel that a lighter dose does the work.

As there was a slight growth in the "Upper" reservoir, we gave that a dose about the last of June, using 20 pounds of sulphate of copper for 4,000,000 of gallons of water. The same effects were noticed as in the "Lower" reservoir, and there has been no growth of algæ since.

The use of the copper sulphate has certainly been most successful in our case. Not only has the water company been saved the considerable cost of repeated cleaning of the reservoirs, but the residents of our village have been saved the annoyance of having at times to use a most unsatisfactory water supply. (September 22, 1904.)

ELMIRA, N. Y.

The following is an extract from an article[a] entitled "The Copper Sulphate Treatment for Algæ at Elmira, N. Y.," by James M. Caird, consulting engineer:

The reservoir was constructed during the year 1870, by building a dam across a natural site. At the time of construction the timber and surface soil were removed from the parts to be flooded. The reservoir has a drainage area of about 4½ square miles, covers 38 acres, and has a capacity, when full, of 113,000,000 gallons. The supply is derived from springs and a small stream called Hoffman Creek.

At various times the water in this reservoir has been a source of trouble owing to its strong "fishy" odor and taste, due to a growth of Anabaena and Asterionella. At times, before the construction of the filter plant, it was necessary on account of the odor and taste to drain and clean the reservoir, the last cleaning being done during the summer of 1889. The growth has been so abundant that even in the winter, when it was necessary at times to use this supply, lime had to be added before filtration in order to remove the "fishy" taste.

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[a] The Engineering News. **52**: 34.

The temperature of the water at the time of treatment was 64° F. In all 1,000 pounds of copper sulphate were used in treating the 90,000,000 gallons. This was equal to 1⅓ parts of copper sulphate per 1,000,000 parts of water, or 1⅓ pounds for every 120,048 gallons of water.

The reservoir was treated June 25, and none of the water was used until June 27, thirty-six hours after treatment. A sample of one liter, taken on June 27 and evaporated to 100 c. c., failed to give the copper reaction when tested with potassium ferro-cyanide.

The Anabaena disappeared thirty-six hours after treatment, while the Asterionella disappeared eighty-four hours after treatment. In looking over the preceding table it is seen that there was a reduction in bacteria of 86.7 per cent in thirty-six hours; 91.8 per cent in eighty-four hours, and 94.3 per cent in one hundred and eight hours.

Before treatment five samples of 1 c. c. each were examined for *B. coli communis*. Two gave positive results. Thirty-six hours after treatment this bacillus could not be found.

In operating the filters it was found that after the treatment the period between washings had been increased three hours, and the wash water was reduced from 2.3 to 1.9 per cent.

The effect of the copper-sulphate treatment on the different animal life was as follows: Numerous "pollywogs" killed, but no frogs; numerous small (less than 2 inches long) black bass and two large ones (8 inches long) killed; about ten large "bullheads" were killed, but no small ones; numerous small (less than 2 inches long) "sunfish" were killed, but no large ones.

The wind brought the dead fish to the corners of the reservoir, and it was very little trouble to remove them. No dead fish were seen twenty-four hours after completion of the treatment.

FIELDHOME, N. Y.

The following extracts from letters of Mr. C. DeP. Field, owner of the estate, summarize the results obtained at Fieldhome, N. Y.

The reservoir is filled by a spring that was for years our sole supply for water, and which was satisfactory. The reservoir is of concrete, about 4½ feet deep, surrounded by trees which do not exclude the sunlight. It has no top, and may derive some of its supply from the rain. The cattle have drunk the water from the overflow without apparent ill effects, but the coloration of the water is unfortunate, and apparently there are algæ in it. (July 8, 1904.)

After treatment.—Day by day we could see the end of a stick inserted in the reservoir, a little deeper. (July 23, 1904.)

The reservoir has cleared sufficiently for the bottom to be seen in places and the stones on the plank put in to walk down for bathing are all visible. (July 28, 1904.)

GLENCOVE, LONG ISLAND, N. Y.

A pond in the vicinity of Glencove, Long Island, was overgrown with small organisms, chiefly *Volvox globator* and *Phacus microcystis*. These are resistant organisms, especially the Phacus, but as is shown in the following extract from a letter from Mr. R. A. Shaw, the owner of the pond, the treatment seemed promising, though it was impossible to get definite results.

I duly carried out your instructions and added the further quantity of sulphate of copper to my pond. I think there has been some improvement, but am unable to tell how much, because the water, as a general rule, begins to clear as the temperature becomes cooler. Under such conditions it will probably be necessary to treat several times during the warm season. (September 28, 1904.)

GREENWICH, CONN.

During the latter part of July Prof. F. S. Hollis, of the Yale Medical School, acting under advice from the Laboratory of Plant Physiology of the Department of Agriculture, treated the two reservoirs supplying Greenwich, Conn.

The following is an extract from a letter received from Professor Hollis, dated August 11, 1904:

> Algæ, especially Anabaena, which were abundant in Putnam reservoir, were completely removed, and a large growth of filaments encased in jelly and attached to waterworks, which was probably a developing stage of some form, almost completely disappeared within a week after treatment. At the upper end of the reservoir there has appeared since the treatment a considerable growth of infusoria. Bacteria increased from ten to twenty times after treatment. In Rockwood reservoir at the dam the total organisms, 384, with Chlamydomonas 93, decreased in four days after treatment to 91 with Chlamydomonas 6. On August 9 organisms had increased to 194 with Chlamydomonas 53 and the complaint as to water is continued as all evidence of the sharp odor of Chlamydomonas is not removed by their method of mechanical filtration. Temperature of Rockwood, 23.6° C.; of Putnam 25° C.

On account of the slight increase of the pollution mentioned in the last sentence of Professor Hollis's letter, a second treatment was advised, the solution used to be of the same strength as the former one. Presumably this was satisfactorily effective, as there has been no further complaint.

HANOVER, N. H.

In the case of the water supply at Hanover, N. H., it was impossible to obtain samples of the organism before treatment was made, and it seems that any one of several species might have been responsible for the pollution, though for geographical reasons it seems probable that the form in question is Uroglena. The following extract from the Eighteenth Report of the board of health of the State of New Hampshire, volume 18 (1903-4), pages 159-161, shows the results obtained:

> On account of the gradual sloping of the banks of the reservoir and the presence of many fish, a 1 to 4,000,000 solution was used. * * * It was estimated that there were about 100,000,000 gallons of water in the reservoir at the time. The copper sulphate was weighed out into 25-pound lots. One lot was placed in a gunny sack, which was held open by an iron spreader, the sack fastened at the top, and then attached to the stern of a rowboat. The boat was rowed back and forth across the reservoir, commencing where the water was deepest and ending along the edges where the water was shallow. This process was repeated along lines 25 to 30 feet apart until the whole area had been covered. The copper dissolved very quickly, the water being warm, which necessitated rowing rapidly while the sack was full and slowing up as the copper in the sack diminished.
>
> Another small body of water was treated in the same way, except in this case a 1

to 1,000,000 solution was used. No bacteriological examination had been made previous to the application to this smaller body of water. The application was made to this water as an experiment in reference to the effect upon the fish.

This body of water was quite shallow at the edges and about 8 feet deep in the center. The application was made in both cases on the same day between 10 a. m. and 3 p. m. The day was very warm, no wind, and a heavy thunder shower took place just as the work was finished. (July 19, 1904.)

The edges of the reservoir were inspected next morning, and no dead fish were found, no odor was noticed, and many very small fish were seen swimming about.

On the edges of the smaller body of water 86 small dead fish were picked up, the largest of these measuring 1½ inches in length. The appearance of these dead fish was very striking. Their abdomens were very much distended and many of them had buried their heads in the mud, and in all cases their eyes looked "popped out" from their sockets. No fish were seen which seemed to be injured. Quantities of fish about 2 inches long, and from that size up to 1 foot long, were seen swimming about in the water apparently in a perfect state of health. Both bodies of water were inspected each morning for four days; no more dead fish were found, and nothing remarkable was seen. There was no perceptible change in the appearance of the water. Samples were taken from the reservoir and from taps in town and examined for micro-organisms, with the following results:

June, 1904, 1,800 micro-organisms, other than algæ, per cubic centimeter.

July 16, 1904, 2,600 micro-organisms, other than algæ, per cubic centimeter.

The above was tap water. Algæ not included in this table:

Date.	Reservoir.	Tap.	Date.	Reservoir.	Tap.
1904.	*Per c. c.*	*Per c. c.*	1904.	*Per c. c.*	*Per c. c.*
July 20	7	2,400	October	(*a*)	840
July 21	5	400	November	(*a*)	800
July 22	15	20	July 16		(*b*)
July 23	20	15	July 20	(*c*)	(*b*)
July 30	(*a*)	40	July 21	(*c*)	(*d*)
August	(*a*)	500	July 22	(*c*)	(*c*)
September	(*a*)	986	July 23	(*c*)	(*c*)

[a] No examination. [b] Large numbers. [c] None. [d] Few.

Last examination for algæ was in August, when only a few grew on media.

The first day after the application the taste and odor had perceptibly diminished, and on the second day had disappeared altogether. The color also practically disappeared, and only a slight color reaction could be detected by delicate color tests. Chemical examination showed no trace of copper in the reservoir water. A sample was not examined from the small pond. No one in town except those immediately concerned in the work knew that anything was being done, but in two days after the treatment two different persons remarked upon the improvement and within a week no less than 11 individuals spoke of it. It is not generally known at this time that anything has been done to the water. Up to date there has been no bad taste, no color, and no odor when cold. At times I think I can detect a very slight odor on close observation when the water is warm.

Conclusion.—That the odor and taste were due to microscopic organisms. The color to a great extent was also due to micro-organisms. That the application of copper sulphate in the strength of 1 part to 4,000,000 of water is sufficient to destroy these organisms without injury to fish. That 1 part of copper sulphate to 1,000,000 parts of water as found in the ordinary reservoirs and ponds will, in addition to destroying micro-organisms, destroy the small fish.

The probabilities are that if the water was of an equal depth in all parts of our reservoirs and ponds 1 part of copper sulphate to 1,000,000 parts of water would not kill the fish, but as the edges are shallow and the bottom irregular, it is impossible to get an equal distribution of the solution until after the smaller fish succumb. There can be no fixed general rule; each case must be treated as conditions require.

HANOVER, PA.

The three reservoirs of this system were badly infested with Anabaena. Treatment was made the latter part of August on the first reservoir and several days later upon the other two. The surface of the water cleared within a short time, but the lower layers containing the decaying algæ were improving but slowly.

The following extract from a letter from Mr. Charles R. Delaney, chemist of the Consumers' Water Company, shows the final results:

> The results of the last test show such great improvement that Mr. Brough has been advised to let the bottom water run off until the odor shows only faintly and then to turn the water into the mains. (September, 1904.)

IVORYDALE, OHIO.

The small reservoir of the Proctor & Gamble Company at Ivorydale, Ohio, was badly infested with algæ. The following is extracted from a letter dated September 22, 1904, from that firm:

> We are glad to be able to report the complete success of the treatment of our reservoir with copper sulphate.
>
> We treated the water as you directed, using approximately one part copper sulphate to a million of water. At this time there were several large floating masses of algæ, and the water had a peculiar odor and taste. We treated the water Saturday afternoon, August 13, and allowed it to remain practically quiescent for several days. Monday morning we found the masses had turned brown in color and frothy, but still floating in the large masses. These masses, however, subsequently disappeared, and since then there has been no sign of the growth except in an old skiff to which the treated water did not penetrate. Here the mass is still green.

JOHNSON CREEK, WIS.

The Geo. C. Mansfield Company reports as follows with reference to the use of copper in two ponds at Johnson Creek, Wis.:

> We used three applications of the solution recommended, and used same in each of our two ponds. The applications were made three days apart and as per your instructions. We had intended to make one more application, but cold weather came on and the ponds froze over; however, from close observation of the results from the three applications, we think it very beneficial. The green moss had about all disappeared or turned scorched or brown color, and evidently was destroyed. We believe late in the fall to be a splendid time to make these applications, as most of the fish are in deep water and do not come in contact with the solution. We did not discover that a single fish was destroyed. (December 5, 1904.)

MIDDLETOWN, N. Y.

The following article, entitled "The Copper Sulphate Treatment for Algæ at Middletown, N. Y.," by James M. Caird, appeared in the Engineering News for January 12, 1905, pages 33–34.

The city of Middletown, N. Y., obtains its water supply from three impounding reservoirs (Monhagen, Highland, and Shawangunk) which are located some distance from the city. The water is filtered before being delivered to the consumers. The filter plant has a capacity of 4,000,000 gallons per day, consists of 4 gravity and 4 pressure filters, each set of 2,000,000 gallons capacity per day.

The water from Monhagen reservoir is used in the lower parts of the city and is passed through the gravity filters, while the elevated section uses the water from Highland reservoir after passing through the pressure filters. The water from Shawangunk reservoir discharges into Monhagen reservoir.

In recent years during warm weather considerable trouble has been experienced by algæ growths, not only by the odor which they produced but also by the rapid "clogging" of the filters. At times the filters would require washing at intervals of four to five hours.

From a sanitary standpoint the quality of these waters is good, the drainage area being owned or controlled by the water department.

Monhagen reservoir.—The Monhagen reservoir, which was constructed in 1867, was the first to be treated with the copper sulphate, the reason being that the greater part of the city's supply is obtained from this source. This reservoir has a drainage area of 300 acres, surface area of 68 acres, and a capacity of 296,000,000 gallons. When treated, this reservoir contained 250,000,000 gallons. The copper sulphate was applied at the rate of 1 part to 3,333,000 parts of water.

Portions of this reservoir were covered with a heavy growth of Potamegeton (pond weed). Three days after the treatment this weed began to come to the surface, and was raked off. Upon investigation it appeared to have rotted at the root. The conditions in this reservoir permitted a very uniform application of the copper sulphate. No fish were killed, although they were present in large numbers.

The examination of this water, before and after the treatment, revealed the following organisms:

	Before.	Fourteen days after.
Diatomaceae:		
Synedra	2	
Nitzschia	4	1
Chlorophyceae:		
Ulothrix	6	
Closterium	3	
Cyanophyceae:		
Oscillaria	6	
Anabaena	15	
Schizomycetes:		
Leptothrix	2	
Crenothrix	2	
Miscellaneous:		
Pleureonema	1	
Notholea	2	
Total per c. c.	43	1
Bacteria per c. c	420	450

The odor from this water before treatment was noticeable at a considerable distance from the reservoir.

Shawangunk reservoir.—This reservoir was constructed in 1902 and has a drainage area of 422½ acres, a surface area of 101 acres, and a capacity of 434,000,000 gallons. There is a large quantity of decaying wood in this reservoir, as the stumps were not removed before the land was flooded. No growth of Potamegeton was shown.

It was very difficult to treat this reservoir in places, owing to the stumps. In going around the stumps the copper sulphate was applied a little stronger than in other parts of the reservoir. The consequence was the death of a few fish.

The organisms found in the water before and after treatment were as follows:

	Before.	Ten days after.
Diatomaceae—Nitzschia	8	1
Chlorophyceae:		
Ulothrix	10	1
Protococcus		1
Cynanophyceae:		
Oscillaria	14	
Anabaena	12	
Schizomycetes—Leptothrix	9	2
Total per c. c	53	5
Bacteria per c. c	300	260

Highland reservoir.—This reservoir was completed in 1891, has a drainage area of 341 acres, a surface area of 110 acres, and a capacity of 560,000,000 gallons. When treated, the reservoir contained 495,000,000 gallons. The copper sulphate was applied at an average rate of 1 part to 2,292,000 parts of water.

There are a large number of "coves" around this reservoir, which necessitated a stronger treatment, resulting in the killing of a few fish. I should estimate the strength of the copper sulphate in these localities at about 1 part to 1,250,000 of water.

As in Monhagen, this reservoir contained a growth of Potamegeton, which broke off after treatment and came to the surface, where it was raked off.

The organisms found before and after treatment follow:

	Before.	Six days after.
Diatomaceae—Nitzschia	7	1
Chlorophyceae—Protococcus	34	3
Cyanophyceae—Oscillaria	5	
Schizomycetes—Leptothrix	5	1
Rotifer:		
Microcodon	10	
Notholca	1	
R. vulgaris	1	
Total per c. c	73	5
Bacteria per c. c	400	360

The temperature of these waters at the time of treatment was about 68° F. The greatest trouble with the waters commenced about the middle of August. The copper sulphate was applied the first part of September, since which time the waters have given no trouble.

The destruction of the algæ in waters which are to be filtered by the mechanical process results in a great saving in the cost of operation. That is, after treatment less coagulant is required to free the water from the suspended matter, the period between the washings of the beds is longer and there is a reduction in the percentage of wash water.

The freeing of the reservoirs of the growth of Potamegeton was also very desirable beecause after its death, which occurs during cold weather, it decomposes and imparts a very distinct yellowish-brown color to the water.

The beneficial results were noticeable twenty-four hours after the application of the copper sulphate to these waters. * * * The total amount of water treated was 1,095,000,000 gallons. The cost of this treatment was as follows:

Copper sulphate, freight and cartage	$186.06
Cartage of boats	5.00
Labor, eighty-three hours, at 15 cents per hour	12.45
Total	203.51

Exclusive of examinations and supervision, this was at the rate of 18½ cents per 1,000,000 gallons of water treated.

MILLERSBURG, PA.

Treatment in the case of the reservoir at Millersburg, Pa., was undertaken by the Millersburg Home Water Company and this laboratory has no record of the organism causing the trouble. The following extracts from reports of T. F. Bradenbaugh, president of the water company, show the condition of the reservoir:

July 31, 1904.—9 a. m., copper sulphate placed in the reservoir, 2 pounds per million; 7 p. m., slight change in the color of the water.

August 1.—7 a. m., color changed considerably; 7 p. m., water clearing.

August 2.—7 a. m., color changed to blue-green and much clearer; 7 p. m., water clearer, bottom of reservoir dimly seen.

August 4.—6 p. m., objects on bottom of the reservoir plainly seen. Small white particles seem to be suspended in the water; these are rapidly settling, leaving the water clear as crystal.

November 12.—After having sent you sample of water, and before receiving your letter dated August 16, the water in our reservoir became so bad both in color and odor that we gave it a second treatment, using the same quantity and method as in treatment No. 1.

The water again cleared and odor disappeared, but not to so marked a degree as after the first treatment. (Several fish died during this treatment.) The effect of treatment No. 2 lasted about three weeks, when the conditions again became so bad that we treated it a third time, with about the same results as No. 2.

After this treatment we changed our pumping system, so that instead of pumping into the reservoir we pumped direct into the pipe lines, allowing the surplus to back up into the reservoir. From that time we have had no trouble, but the water in the reservoir still retained its greenish color until cold weather came; now it is changing and is nearly as clear as crystal again.

It seems that deep-well water, if allowed to lie in a shallow basin or reservoir under a hot sun, will develop these troubles with great rapidity.

By tracing down the source of contamination and thoroughly sterilizing that, as well as treating the reservoir, there seems every probability that this polluting form could be eradicated.

MONCTON, NEW BRUNSWICK.

The report upon the conditions and effect of treatment at Moncton is of especial interest on account of being the only one dealing with an icebound reservoir. The following extracts from letters from Mr. J. Edington, city engineer, and from the Daily Times, of Moncton, show the method of treating and the results obtained:

Our trouble is almost entirely confined to the winter months, when the reservoir is frozen over. It varies more or less according to the length and severity of the winters, but the past two have been particularly bad.

In 1903 and 1904 the reservoir was frozen over on the 20th of November, and on the 17th of January the odor and taste commenced. This continued until the 7th of March, when the spring rains and freshets brought relief.

The conditions this winter are very much the same. Openings have been kept in the ice, but with zero weather they are not much good, as the ice forms as soon as holes are made.

The reservoir has a capacity of 200,000,000 gallons and is 30 feet deep at the gate house, and it is noticeable that the top layer of 5 feet is comparatively free from taste and odor, while at 10 or 15 feet the trouble is bad.

If the copper sulphate treatment has to be done in the winter, could it be effectively applied when the ice is from 2 to 3 feet thick? (February 13, 1905.)

The daily consumption of water is 1,250,000 gallons in twenty-four hours. How would it do to place, say, one-fourth of a pound in gate house every six hours, or a lesser quantity oftener, so that the proportion would be 1 pound per million gallons? Of course there is no current in gate house, as the water remains at same head as in reservoir. (February 24, 1905.)

The experiment was commenced at noon on the 8th instant by suspending two bags of copper sulphate, each containing 2 ounces, on a level with inlet pipes in gate house.

The daily consumption of water is estimated at 1,250,000 gallons, but the quantity of copper sulphate was based on 1,000,000 gallons, the idea being to apply 4 ounces every two hours, thus giving 1 pound per million gallons.

It was found that the crystals dissolved too quick, and the quantities were changed to 2 ounces every three hours.

A large opening, 100 feet by 40 feet, is cut in the ice adjacent to gate house and immediately over intake pipes. This has also been treated every second day by the application of 1 ounce forenoon and afternoon, this quantity being put in a small bag attached to a long pole and trailed up and down through the water until dissolved, the object in view being to get as even a distribution as possible of 1 pound of copper sulphate per million gallons every twenty-four hours. The result has been a great improvement in the water not only in the taste and odor, but in its color. (March 14, 1905.)

The experiment was tried several days ago, and immediately an improvement was noticeable in the water. Yesterday the improvement was so marked that it was a matter of comment among the citizens. The improvement, however, was attributed to the melting snow; but as a matter of fact there has been no new water from this source up to the present time. * * * Engineer Edington is satisfied that a solution of the trouble with the water in the winter season has been found. (The Daily Times, Moncton, New Brunswick, March 14, 1905.)

NEW YORK, N. Y.

The following extract is taken from a paper read before the American Chemical Society[a] by Mr. Daniel D. Jackson, chemist in charge of the Mount Prospect Laboratory in Brooklyn:

The department of water supply and the department of parks of New York City have both had waters treated by the author during the summer with decided success, and in each case only one treatment extending for a period of one hour was necessary.

NEWTOWN, PA.

The reservoir at Newtown, Pa., is a small one, with a summer temperature close to 60° F. The number of *Scenedesmus caudatus* per cubic centimeter was sufficient to give a decided green color to the water, and a scum or film would form during quiet weather. As the organism is a resistant one, two treatments were made about one week apart.

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[a] Science, **20**: 805. See also The Engineering Record, October 29, 1904.

Mr. T. J. Kenderdine, of the Newtown Water Company, gives an account of the work in the Intelligencer, from which the following is quoted:

The Newtown Artesian Water Company was put in operation sixteen years ago, and was a case of ground water pumped into an open basin. The water was analyzed as chemically pure, and in the absence of knowledge of alga the managers were surprised to find a discolorization in it the coming summer, with a taste as it increased that brought complaint from the consumers. To relieve this the water was let out, when a green sediment was found coating the bottom and sides of the basin. This was removed by a thorough flushing and scrubbing with stiff brooms, when it was thought the trouble was over. This was not the case, and for the past sixteen years there has been a repetition of this attempt to remedy the evil, which was found to be a vegetable growth in the water developed by the sun or to exposure in an open basin. The only way after it appeared in April was to empty the reservoir weekly, after running the water down to a depth of two and a half to three feet, and refill it; then, at the end of each month or six weeks, have a general scrubbing and brushing of the sedimented water to a prepared depression, where it was pumped or carried over the rim of the basin in buckets. The only other remedy for riddance of the pest was to roof over the whole surface, to erect a brick cistern in the center of sufficient size for household needs, and with an outlet for the main body of water in case of fire, the inlet from the pumping station coming up through the center, and roof that in, and thereby save the prohibitory expense of covering the whole reservoir, or to pump night and day into the street mains to give the consumers fresh water, and leave a stagnant pool in the basin, or throw away the work spent on erecting the basin and erect a standpipe. All these were thought of by those interested, but the cost and uncertainty of results deterred action, and the alga trouble seemed as if it would stretch out indefinitely into the future, with its cost of riddance and drain on the coal pile to replace the lost water from wells from 150 to 200 feet deep to a storage basin 60 feet above their surfaces. The remedy, however, without the expenses these would involve was not far off.

The second application was made September 24, when it was found a marked change had taken place for the better in the character of the water. The greenness was going and so was the fishy taste.

Nine days later an examination of the reservoir was made, when it was shown that the water was absolutely clear and that there was no need of further treatment. It is now three months since the water has been let out or the reservoir cleaned, and the effect of the small amount of copper used is marvelous. The water in the basin is as clear as a lake, and comes from the household faucet as if piped from a spring. The days of letting out alga-infected water and its replacement, as well as the monthly cleaning, which was looked for as surely as the new moon in the warmer seasons, are now of the past, and, as a matter of course, the hours for pumping lessened, as well as the drain on the coal pile, and, better than all, there was no longer any complaints coming from the consumers. In dollars and cents the cost of the new mode was not over $1, while the old way would have been $60 in the time since the last cleaning of the reservoir.

OBERLIN, OHIO.

George N. Carruthers, Springdale Farm, reports as follows:

You may recall my visit at your headquarters last spring, and your call at my farm to inspect my water-lily and lotus pond, and your recommendation for the destruction of algæ. Your remedy was entirely successful. (October 24, 1904.)

PASSAIC, N. J.

It is evident that the source of contamination at Passaic, N. J., has not been eradicated, and it seems that with the location and treatment of this source the water could be kept in good condition. The lake is a small one, owned by a land improvement company. Mr. Frank Hughes, agent for the company, writes:

> We have treated the lake twice this summer, and the last time we also applied the copper sulphate to the little pond above. There has been a slight return of the algæ, but so far it has not been enough to require another treatment. After the second treatment last summer there was no return of the algæ until about the middle of June this present summer. (September 19, 1904.)

PORT DEPOSIT, MD.

Early in May the water in the small reservoir supplying the Jacob Tome Institute at Port Deposit, Md., was in rather bad condition, due chiefly to the presence of Chlamydomonas. Treatment was made May 6, 1904, and on September 26 President A. W. Harris wrote as follows:

> The improvement in the taste and odor of the reservoir water was extremely marked. The water is now in a very satisfactory condition.

RHINEBECK, N. Y.

George N. Miller reported as follows on September 27, 1904, with reference to the success obtained in using copper in the lake on his estate at Rhinebeck, N. Y.:

> On August 3 I added 10 pounds of copper sulphate to my lake, and on August 5 there were hardly any signs of algæ left. About September 1 I treated again, as the algæ had reappeared, especially in the lower part of the lake. This time it was only fairly successful. It seemed to kill off about half of the algæ. A second application three days afterwards seemed to have but little effect. I should say that to kill completely needed a much stronger solution. The amount I used certainly did no harm to cattle, sheep, etc., and did not kill any fish.

The alga causing the trouble is a rather resistant filamentous form, but one which should be easily eradicated by treating as soon as the warm season begins to cause rapid development, and probably again late in the summer.

SCARBORO, N. Y.

The following is a report of the treatment of a pond on the estate of James Speyer.

> I dissolved 100 pounds of copper in the pond. Now there is not a bit of water-net to be seen. (July 25, 1904.)
>
> The quantity I roughly estimate at about one-half the quantity which you advised, but that solution did its work effectively and the algæ began to discolor in about twenty-four hours, and after thirty-six hours entirely disappeared, sinking to the bottom.

It is, however, only just for me to add that with the continuation of the hot weather the pond developed a rather disagreeable odor, and I also found several dead eels in the pond. Whether this odor is due to some fish which died on account of the copper sulphate or to the decaying of the plants which had sunk to the bottom I cannot tell, but in former years when the water supply was about the same as this year I did not notice the smell. (September 20, 1904.)

If the alga was allowed to develop until it was forming large masses it is to be expected that during its decay, subsequent to treatment, it would give off a very decidedly disagreeable odor.

SPRINGFIELD, ILL.

Arthur Hay, secretary-engineer of the Pleasure Driveway and Park District, of Springfield, Ill., wrote, under date of September 21, 1904, regarding the use of copper in a park lake, as follows:

The custodian reports that he has used 2 pounds of copper sulphate in a pond containing about 2,000,000 gallons of water thickly planted with water lilies and stocked with fish. The surface of the water was covered with a "brownish scum" [probably Spirogyra]. A few hours after the application of the sulphate the scum disintegrated into a curdy precipitate which remained entangled about the stems of the water lilies.

After waiting several days for this to disappear, and observing no change, he drew off the water, and after cleaning the pond refilled it with fresh water. He has not noticed any growth of the scum since. Neither the water lilies nor the fish were affected by the use of the sulphate. In another pond, with no water lilies, but bordered with cat-tails and aquatic grasses, there was no scum, but a heavy growth of a "stringy green moss." He applied copper sulphate here in the strength at first of 1 pound to 1,000,000 gallons of water, and later considerably stronger, but noticed no effect either on the moss or the cat-tails.

WALTHAM, MASS.

Bertram Brewer, city engineer, reported trouble due to algæ in the watering tubs in his pasture. Mr. Brewer wrote as follows on September 24, 1904:

Soon after I received your directions I filled the tubs with copper sulphate solution and let it stand in one tub forty-eight hours, in the other about a week. The result was that I have not had to repeat the dose oftener than once in three weeks. I found that a careful washing in the copper solution also prevented the growth of mosquitoes in my tubs, and that made it doubly desirable.

This is of interest on account of again bringing up the matter of the destruction of mosquito larvæ in pure water by copper sulphate.

WATER MILL, LONG ISLAND, N. Y.

The following letter, dated December 28, 1904, from Dr. Thomas T. Gaunt, New York City, is self-explanatory:

My place in the country is located at Water Mill, in the township of Southampton, in Long Island. I purchased it in April, 1902, and was largely influenced in selecting this piece of land by the beauty of a pond which bounds it on the east. This little body of water covers about 2 acres, is fed by numerous springs, and discharges into Mecox Bay, the southern boundary of the land. When I bought the place the pond was filled with clear water. About the middle of the following June algæ began to show, and in August the surface was almost entirely covered by the growth. The odor was offensive, and myriads of small insects hovered over the masses of algæ much of the time. I consulted two engineers interested in the storage of water, and they told me nothing could be done. The condition was so objectionable that I planned to plant a thick hedge of willows along the bank to shut off the view of the pond from the house. * * * I examined the pond on June 15 and found large masses of algæ covering an area several hundred feet in length and from 20 to 40 feet in width. No microscopical examination was made of the growth, but I was informed that it seemed to be largely composed of filaments of Spirogyra and other Conferveæ. On June 18 the treatment was begun. * * * In one week the growth had sunk and the pond was filled with clear water. I examined the pond on September 15 and found it still clear. From time to time during the summer small masses of algæ appeared along the banks, but they were only apparent on close inspection.

The use of the sulphate of copper converted an offensive insect-breeding pond into a body of beautifully clear water. The pond was full of fish, but the copper did not seem to harm them.

WELLSBORO, PA.

Anton Hardt, Wellsboro Water Company, wrote on August 16, 1904:

May 26 I distributed 15 pounds of sulphate of copper as directed by you. The algæ turned brown in three days and disappeared entirely inside of two weeks. There is no perceptible odor from the water at present.

WINCHESTER, KY.

William Wheeler, consulting engineer, Boston, Mass., wrote on September 14, 1904, as follows:

Among the many sources of water supply with which I have had relations as engineer and manager, under both municipal and private ownership, none has approached that for Winchester, Ky., in the intensity of the development of algæ therein or in offensiveness of the results arising therefrom.

The works were constructed in 1890, the source of supply being the impounded waters of a creek in the Blue Grass region, in which the flow varies from a violent torrent in times of heaviest rainfall to sometimes no appreciable flow whatever during one to three or four months of the driest summers.

The odor first appeared in a noticeable degree during the hot summer months two or three years after the works were constructed, and gradually increased from year to year—mitigated to some extent by means of filtration and æration, yet nevertheless attaining to such a degree of offensiveness two years ago as to make its use for any purpose almost intolerable.

In April, 1903, I applied to Mr. Albert F. Woods, Pathologist and Physiologist of the Bureau of Plant Industry, to enlist the services of Doctor Moore in treating the Winchester reservoir by the copper sulphate process, and the results have been briefly set out in Bulletin No. 24 of the Bureau.

The treatment has once been renewed this season, and the water has thereby been kept entirely inoffensive to the senses of taste, smell, and sight, and made satisfactory to the owners of the works and the community which they serve.

The economic value of the treatment appears to be measured by what it would have cost to procure and maintain an entirely new and independent supply, the only practical source of which is the Kentucky River, at a distance of nearly 10 miles from the town and over 500 feet below it in elevation. The cost of installing and operating the additional works that would be required would be about twice as great as the cost of building and operating the present supply works.

Charles F. Attersall, superintendent of the Wincnester waterworks, under date of October 8, 1904, said:

> The treatment of the reservoir was made on July 19, 1904, with a solution of 1 to 4,000,000 copper sulphate. The treatment was considered necessary owing to the appearance of Anabaena and a perceptible increase in odor. The solution was distributed through the reservoir in practically the same way as applied last year. The result of this treatment has been entirely satisfactory, and we have had no occasion to repeat it. The water has been in excellent condition all the year, with the exception of a very slight odor at the time the solution was applied. We have had no complaints from the consumers, which is the first time since the completion of the plant in 1891.

WINNEBAGO CITY, MINN.

The use of copper in this instance was for the purpose of removing the odor caused by the decay of Lemna and sedge that grew and decayed rapidly in the cooling pond of the Winnebago Flour Mills Company The amount applied was far in excess of what would be practicable if fish were present, and illustrates merely an incidental use of copper sulphate. S. W. Tredway, of the above company, wrote on September 17, 1904, as follows:

> We have applied sulphate of copper twice, putting same in a bag at a time when our pond was still and dragging it all around. We used 3 pounds of copper with each treatment. We have not been running hot water into the pond for some three or four weeks because of the fact that our condenser gave out, and we are now installing a new one, and consequently there has been no current through the pond during all this time.
>
> The copper has completely removed the odor arising from the pond, and there is no question but that the growth has been checked, and from appearances we should think that the weeds are commencing to die off. We probably will not be in a position to say definitely just what the results are before next spring. We are going to make an effort in the early spring to prevent a new growth entirely.

NECESSITY FOR DETERMINING THE POLLUTING ORGANISM.

Before the quantity of copper required in a particular reservoir can possibly be determined it is absolutely necessary to ascertain the exact character of the organism causing the trouble. This makes a microscopical examination of the first importance. Also, the earlier in its development the presence of the polluting form is revealed, the more effective will be the treatment. If examinations are made at short intervals throughout the year, the first appearance of the troublesome algæ can be noted, and by treating promptly at the first sign of their decided increase it is possible to destroy them before the consumer is caused any annoyance. This makes a considerable difference in the expense of treatment also, as it may require fifteen to twenty times as much copper to clean a reservoir after the bad taste and odor are evident as it would if the application had been made before the organism had established itself.

In all cases the use of copper is advocated as a preventive rather than as a cure, and the treatment can not be intelligently applied unless the microscopical examinations are thorough and frequent at the time of year the trouble is to be expected.

TROUBLESOME FORMS AND THEIR IDENTIFICATION.

The bad odors and tastes due to the presence of algæ may be due either to a definite secretion from the plant or to its decomposition. In most water supplies the difficulty is first evident before the algæ have begun to die, and, although the objectionable conditions may be augmented by subsequent decay, there are comparatively few alga-infested reservoirs in which the disagreeable effect is not originally produced by the living algæ. The effects directly produced by these plants have been so variously described that it is difficult to arrange any classification which will enable one to identify the organism by the odor or taste produced. In general, however, it may be said that the diatoms cause what has been termed an "aromatic" odor, although if in great quantity it is apt to be nauseating and fishy. Uroglena, which in this country usually appears during the winter months, is the form causing the most characteristic fishy taste and odor. Volvox is reported to have a similar effect. There are also certain forms closely related to both Uroglena and Volvox which at times may produce a flavor suggestive of fish.

During the summer by far the greatest difficulty in water supplies infested with algæ is due to the blue-greens, or Schizophyceae. The odor first noticeable has been described as grassy or moldy, but this usually changes as decay sets in to a pronounced "pig-pen" odor, which can frequently be detected for a considerable distance from the reservoir. Many of the larger grass-green algæ, such as Cladophora, Conferva, Spirogyra, Hydrodictyon, etc., cause trouble by being present in such quantities as to produce a distinct vegetable odor when they begin to disintegrate.

As many of the algæ occurring in water supplies are very minute, it is often necessary to resort to special methods to collect samples for identification. In some instances it is sufficient merely to allow a jar of the water in question to remain undisturbed for a few hours, when the algæ will have settled to the bottom, and it will be possible with the aid of a pipette or a small glass tube to remove a sample of this deposit to the glass slide for examination. If the organisms are motile, or if it is desired to estimate their number per cubic centimeter, the method described as the Sedgwick-Rafter method is the best for this purpose. The numerous requests for a means of determining quantitatively the algæ in water warrants the following extensive quotation:

THE SEDGWICK-RAFTER METHOD OF QUANTITATIVE DETERMINATION.[a]

The Sedgwick-Rafter method consists of the following processes: The filtration of a measured quantity of the sample through a layer of sand upon which the organisms are detained, the separation of the organisms from the sand by washing with a small measured quantity of filtered or distilled water and by decanting, the microscopical examination of a portion of the decanted fluid, the enumeration of the organisms found therein, and the calculation from this of the number of organisms in the sample of water examined. The essential parts of the apparatus are the filter, the decantation tubes, the cell, and the microscope with an ocular micrometer.

The filter.—The sand may be supported upon a plug of rolled wire gauze at the bottom of an ordinary glass funnel 7 or 8 inches in diameter, but the cylindrical funnel * * * is preferable. The inside diameter of this funnel at the top is 2 inches, the distance from the top to the beginning of the slope is 9 inches, the length of the slope is about 3 inches, the length of the tube of small bore is 2½ inches, and its inside diameter is one-half inch. The capacity of the funnel is 500 c. c. The support for the sand consists of a perforated rubber stopper pressed tightly into the stem of the funnel and capped with a circle of fine silk bolting cloth. The circles of bolting cloth may be cut out with a wad cutter. Their diameter should be a little less than that of the small end of the rubber stopper. When moist, the cloth readily adheres to the stopper. The sand resting upon the platform thus prepared should have a depth of at least three-fourths of an inch. The quality of the sand is important. Ordinary sand is unsatisfactory unless very thoroughly washed. Pure ground quartz is preferable. Its whiteness is a decided advantage. The necessary degree of fineness of the sand depends somewhat upon the character of the water to be filtered. A sand which will pass through a sieve having 60 meshes to an inch, but which will be retained by a sieve having 120 meshes, will be found satisfactory for most samples. Such a sand is described as a 60–120 sand. When very minute organisms are present a finer sand must be used, say, a 60–140 sand. The sand used for many years by the author had the following composition:

Size of sand grains.	Percentage by weight.
40– 60	20
60– 80	20
80–100	38
100–120	18
120–140	4
....	100

The sample to be filtered may be measured in a graduated cylinder or flask, or the filter funnel itself may be graduated. The graduated filter funnel is especially useful for field work, as it saves the necessity of carrying an additional graduate. The quantity of water that should be filtered depends upon the number of organisms and the amount of amorphous matter present. An inspection of the sample will enable one to judge the proper amount. Ordinarily 1,000 c. c. for a ground water and 500 c. c. for a surface water will be found satisfactory. In some cases 250 c. c. or even 100 c. c. of a surface water will be found more convenient. When the water is poured into the funnel, care should be taken not to disturb the sand more than is necessary, otherwise organisms are liable to be forced through the filter. The best plan is to make the sand compact by pouring in enough distilled water to just about fill the neck of the funnel and to pour in the measured sample before the sand has become uncovered. The filtration ordinarily takes place in about half an hour, but occasionally a sample is so rich in organisms and amorphous matter that the filter becomes clogged. It then becomes necessary to agitate the sand with a glass rod or to apply a suction to hasten the filtration. If the filters are located near running water an aspirator may be attached to the faucet and connected with the filter by a rubber tube having a glass connection that fits the bore of the rubber stopper. The use of the aspirator enables the filtration to be made in a few minutes, and not only effects a saving in time, but reduces the error caused by the organisms settling on the sloping surface of the funnel.

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[a] The Microscopy of Drinking Water, by G. C. Whipple, New York, 1899, p. 15.

Concentration.—As a result of the filtration the organisms and whatever other suspended matter the sample contained will have been collected on the sand. When all the water has passed through and before the sand has become dry the rubber stopper is removed and the sand with its accumulated organisms is washed down into a wide test tube by a measured quantity of filtered or distilled water delivered from a pipette or an automatic burette. The amount of water used for washing depends upon the number of organisms collected on the sand. If 500 c. c. of the sample are filtered it is usually best to wash the sand with 5 c. c., thus concentrating the organisms one hundred times. The amount of water filtered divided by the amount of water used in washing the sand gives the "degree of concentration." The degree of concentration may vary from 10 to 500, according to the contents of the sample. Ordinarily it should be 50 or 100.

By shaking the test tube the organisms will become detached from the sand grains. If this is followed by a rapid decantation into a second test tube most of the organisms, being lighter than the sand, will pass over with the decanted fluid, while the sand is left upon the walls of the first tube. To insure accuracy the sand should be washed a second time and the two decanted portions mixed together. If, for example, it is desired to concentrate a sample from 500 c. c. to 10 c. c., the sand should be washed twice with 5 c. c. and the two portions poured together. This will give a more accurate result than a single washing with 10 c. c.

It is necessary to allow for the volume of the sand and to use a definite amount of sand at each filtration. The 60–120 sand holds about 50 per cent of water, and ordinarily about 2 c. c. of the sand are used; hence an allowance of 1 c. c. must be made for the water held in the sand.

The cell.—The cell into which a measured portion of the concentrated fluid is placed for examination is made by cementing a rectangular brass rim to an ordinary glass slip. The internal dimensions of the cell are: Length, 50 mm.; width, 20 mm., and depth, 1 mm. It therefore has an area of 1,000 sq. mm. and a capacity of 1 c. c. A thick cover glass (No. 3) having dimensions equal to those of the outside of the brass rim (55 mm. by 25 mm.) forms a roof to the cell. The concentrated organisms in the decantation tube are distributed uniformly through the fluid by blowing into it through a pipette, and 1 cubic centimeter of the fluid is then transferred to the cell in such a manner as to distribute the organisms evenly over the entire area. This may be done by laying the cover glass diagonally over the cell so that an opening is left at either end, and flowing the water in at one end while the air escapes at the other.

The microscope.—An expensive microscope is not needed for the numerical estimation of the common microscopic organisms found in water. A simple, compact stand with a one-half inch objective and a 1-inch ocular is sufficient. For studying the organisms in detail and for general laboratory use in the study of water a large stand, with substage condenser, iris diaphragm, mechanical stage, etc., should be provided. The list of objectives should include a 2-inch, a one-half inch, a one-fourth or one-sixth inch, and a one-twelfth inch homogeneous immersion, or their equivalents, and there should be several oculars magnifying from four to twelve times.

The ocular micrometer consists of a square ruled upon a thin glass disk, which is placed upon the diaphragm of the ocular. The square is of such a size that with a certain combination of objective and ocular and with a certain tube length of the microscope, the area covered by it on the stage is just 1 square millimeter. For convenience it should be subdivided, as shown in fig. 6. The size of the largest square is 1 square millimeter. The size of the smallest square is one standard unit. The standard unit is represented by the area of a square 20 microns on a side—i. e., by 400 square microns. With a one-half-inch objective and a No. 3 ocular the square ruled for the ocular micrometer should be 7 mm. on a side. Before using the micrometer the proper tube length must be ascertained by comparison with a stage micrometer.

Enumeration.—The cell, filled with the concentrated fluid, is placed upon the stage of the microscope and the organisms included within the area of the ruled square are counted. It is then moved so that another portion of the cell comes into the field of view and another square is counted. This is continued until a sufficient number of representative squares have been examined. It is obviously impracticable to count all of the 1,000 squares which compose the area of the cell. It is usually sufficient to count ten or twenty squares, but a larger number ought to be scrutinized. In counting the organisms it should be remembered that some are heavy and sink to the bottom, while others are light and rise to the top. The observer should make a practice of changing the focus of the microscope so that both the upper and lower portions of each square may be examined.

From the number of organisms found in the ten and twenty squares it is an easy matter to calculate the number originally present in 1 cubic centimeter of the sample. If t represents the number of organisms found in 20 squares, $\frac{t}{20}$ will represent the number found in one square, and $50\,t\ (=\frac{t}{20}\times1000)$ will represent the number in the entire cell, or in 1 cubic centimeter of the concentrated fluid. This divided by the degree of concentration will give the number of organisms in 1 c. c. of the sample.

KEY FOR IDENTIFYING ALGÆ.

The following short key is given as an aid to those who have not access to the voluminous and scattered literature on algæ, in the hope that by this means forms which would otherwise remain unidentified may be recognized and treatment made to the best advantage.

Conjugatae.

Grass or yellow green algæ whose cells always divide in the same direction forming single cells or united into unbranched threads or filaments; no swarm spores. Produces zygospores, and occasionally akinetes and aplanospores.

Cell almost divided into two symmetrical halves by a constriction or thinning of the cell contents; almost always with double-layered membrane. Single, or occasionally united into threads.......................................A. Desmidiaceae.

Cells cylindrical, without constriction. United into threads....B. Zygnemaceae.

A. Desmidiaceae.
  (*a*) Cells with only slight constriction.
    I. Cells lunate ....*Closterium.*
  (*b*) Cells with pronounced constriction.
    I. Cells twice as long as wide.
      1. Contour of cells 3 to 5 pointed..........................*Staurastrum.*
      2. Contour of cell round or oval; smooth.
        * Cells free ....*Cosmarium.*
        ** Cells united into a mass of jelly...................*Micrasterias.*

B. Zygnemaceae.
  Two axil star-shaped chromatophores in each cell........................*Zygnema.*
  One or more peripheral spiral chromatophores........................*Spirogyra.*

CHLOROPHYCEAE.

Grass or yellow green algae, single, or united into threads, plates, or masses. Form true spores, swarm spores, akinetes, and aplanospores. Constituting all of the green algae not included in the Conjugateae.

- (*A*) Cells with one nucleus, frequently united into a gelatinous colony.
  - (*a*) Vegetative state actively motile ....A. Volvocaceae.
  - (*b*) Vegetative state not motile.
    - I. Vegetative cell division for increase of colonies; without swarm spores ....B. Pleurococcaceae.
    - II. Without vegetative cell division, cells single ....C. Protococcaceae.
    - III. Cells united to form colonies of definite form..D. Hydrodictyaceae.
- (*B*) Cells with one or many nuclei united to form simple or branched threads, or rarely one or more layered plates.
  - (*a*) Vegetative cells with only one nucleus.
    - I. Thallus of one or more layered plate, free or attached at base. E. Ulvaceae.
    - II. Thallus consists of a simple or branched cell series.
      - 1. Unbranched filaments...........................F. Ulothricaceae.
      - 2. Branched filaments......................G. Chaetophoraceae.
  - (*b*) Vegetative cells with many nuclei, simple or branched filaments.
    - I. Spore formation by union of swarming gametes. Filaments simple or branched, with base and point of growth. Division of filaments not dorsiventral.........H. Cladophoraceae.

A. Volvocaceae.

- (*A*) Cells single.
  - (*a*) Cells with a thin white covering which does not form two valves.
    - I. The integument thickened on one side. Cilia arising directly from the rounded forward end...........................*Chlamydomonas.*
- (*B*) Cells united to form definite colonies.
  - (*a*) Round or oval colonies in a gelatinous envelope with cilia projecting from all sides.
    - I. Colonies of 16 cells...................................*Pandorina.*
    - II. Colonies of 32 cells....................................*Eudorina.*
    - III. Colonies of very many cells forming a large sphere........*Volvox.*

B. Pleurococcaceae.

- (*A*) Cells neither possessing gelatinous sheath nor embedded in jelly.
  - (*a*) Cells single.
    - I. Cells sickle-shaped or lunate...........................*Raphidium.*
  - (*b*) Cells arranged in a plane.
    - I. Colonies arising through division in one direction......*Scenedesmus.*

D. Hydrodictyaceae.

- (*A*) Colonies hollow within.
  - (*a*) Cells cylindrical, long ....*Hydrodictyon.*

E. Ulvaceae (marine).

- (*A*) Thallus membranaceous, plate. Consists of two layers of cells.......*Ulva.*
- (*B*) Thallus membranaceous, tube forming. Cells in older part slightly or not at all arranged in definite order...........................*Enteromorpha.*

F. Ulothricaceae.
(*A*) Cross walls of equal thickness.
(*a*) Swarm-spores present, escaping through a round hole in the cell wall.
I. Filaments long; cells all alike .... *Ulothrix.*
(*b*) Swarm-spores escape by breaking across the cell wall. Chromatophores consist of little orbicular plates.
I. The filament has one pedicle and numerous cells.......... *Conferva.*

G. Chaetophoraceae.
(*A*) Thallus not epiphytic, established with a basal cell or ground cell, seldom spherical or united into a spherical gelatinous mass.
(*a*) A clearly defined main stem present.......... *Draparnaldia.*
(*b*) No clearly defined main stem present.
I. Branches ending in hair points.......... *Stigeoclonium.*

H. Cladophoraceae.
Thallus consists of branched filaments. Branches irregular or forming a radial clump; akinetes absent .... *Cladophora.*

SCHIZOPHYCEAE.

(*A*) Plants consisting of a single cell, occasionally united into colonies by being embedded in a gelatinous matrix..........I. Coccogoneae.
(*B*) Plants having always more than one cell, forming simple or branched filaments, which may or may not be inclosed in an outer gelatinous layer or sheath ....II. Hormogoneae.

(I) Coccogoneae:
(1) Cells free or only slightly held together, not forming a definite colony .... *Chroococcus.*
(2) Cells held together in a gelatinous matrix and forming colonies of regular outline.
(*a*) Colonies at first solid, several rows of cells thick, becoming saccate and perforated.......... *Clathrocystis.*
(*b*) Colonies hollow, cells only on outer surface.......... *Cœlosphaerium.*

(II) Hormogoneae:
(1) Cells generally differentiated into three kinds: (1) Vegetable cells; (2) spores; and, (3) heterocysts. The latter usually are of different color, clearer contents, and with thickenings in the walls adjoining the vegetative cells or spores..........(*a*) Heterocysteae.
(2) Cells in each filament undifferentiated. No heterocysts.
(*b*) Homocysteae.
(*a*) Heterocysteae:
+ Filaments irregularly interwoven and contorted, inclosed in a definite gelatinous mass.......... *Nostoc.*
++ Filaments free or but slightly united.
Ø Heterocysts and spores intercalary.
* Filaments free or united in formless mass... *Anabaena.*
** Filaments densely agglutinated in fascicles, often of considerable size .... *Aphanizomenon.*
ØØ Heterocysts and terminal spores contiguous.
Cylindrospermum.
(*b*) Homocysteae:
+ Filaments simple, with an evident sheath.......... *Lyngbya.*
++ Filaments simple, sheath wanting or very slight, plants possessing a characteristic movement.......... *Oscillatoria.*

METHOD OF APPLYING COPPER SULPHATE.

Before introducing the copper sulphate it is necessary to determine accurately the volume of water to be treated. This is imperative in the case of municipal supplies and large reservoirs, as an error in the the estimation might cause considerable inconvenience. Many cases will arise, however, in which a rough computation will be much more convenient and entirely practicable.

The method considered most practicable in introducing copper sulphate into a water supply has been outlined in a previous publication,[a] from which we quote:

> Place the required number of pounds of copper sulphate in a coarse bag—gunny sack or some equally loose mesh—and attaching this to the stern of a rowboat near the surface of the water, row slowly back and forth over the reservoir, on each trip keeping the boat within 10 to 20 feet of the previous path. In this manner about 100 pounds of copper sulphate can be distributed in one hour. By increasing the number of boats and, in the case of very deep reservoirs, hanging two or three bags to each boat, the treatment of even a large reservoir may be accomplished in from four to six hours. It is necessary, of course, to reduce as much as possible the time required for applying the copper, so that for immense supplies with a capacity of several billion gallons it would probably be desirable to use a launch, carrying long projecting spars to which could be attached bags each containing several hundred pounds of copper sulphate.

The substitution of wire netting for the gunny-sack bag allows a more rapid solution of the sulphate, and the time required for the introduction of the salt may thus be considerably reduced.

The temperature has such great influence on the effect of copper upon polluting forms that it is best to select as warm a day for treating as circumstances will permit.

STERILIZATION OF BACTERIA-POLLUTED WATER BY MEANS OF COPPER SULPHATE.

Treatment with copper sulphate is an effective and practicable means of sterilizing water polluted with certain pathogenic bacteria, and as an emergency method is applicable to both household and municipal conditions. It should prove particularly useful in very large water supplies accidentally or suddenly contaminated with typhoid bacilli and not provided with any adequate means of purification. Under such circumstances the case becomes not one of pure water versus water containing copper sulphate, but of sterile water containing an amount of copper not dangerous to health versus water and typhoid bacilli. The method formerly suggested[b] for treating a reservoir would undoubtedly be advisable in special cases of unusually great contamination when the water contained an abnormal amount of organic matter, but in general an epidemic could be controlled and quickly eradicated by a solution much weaker than the 1 to 100,000 listed as necessary for complete sterilization within twelve hours. One to 2,000,000 is sufficient in most cases, and even less than this quantity of copper is of decided benefit in certain kinds of water.

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[a] Bulletin No. 64, Bureau of Plant Industry, p. 25.

[b] Ibid., p. 33.

STERILIZATION OF THE WATER SUPPLIES AT COLUMBUS, OHIO, AND ALBUQUERQUE, N. MEX.

For many years Columbus, Ohio, has had a high typhoid rate, and the last few years have been a period of almost continuous epidemic. After some correspondence with this laboratory, Dr. McKendree Smith, health officer of the city, decided that copper sulphate offered a means of dealing with these exceptionally dangerous conditions. He accordingly treated the water supply and has recently made the following significant report:

> The Scioto River furnishes the main source of water supply to the city of Columbus, Ohio. Under ordinary conditions it is constantly menaced by innumerable sources of pollution. The limestone quarries, situated on both sides of the stream and extending 2 miles along the banks, employ over 300 men, many of whom are housed with their families in small buildings about the quarries on the extreme edge of the river's banks. A dozen or fifteen small houses, in which large Italian families live, are located in and about the old State quarries, which are also within a few feet of the river bank. A number of villages nestle dangerously near the river. The girls' industrial home (an institution caring for about 800) discharges its sewage directly into the river about 18 miles above the intake. Many small tributaries carry their share of pollution into the stream. These constitute the ordinary and always present dangers to the city's water supply. Recently, however, other grave dangers were added. During the past eight or ten months about 200 men, living in tents and temporary huts, employed in constructing a storage dam, clearing the river banks of trees and undergrowth, and in building the C., U. and W. traction line, by their presence and the manner in which they were compelled to live, increased to no inconsiderable degree the already too great dangers.
>
> To successfully police such a water supply is impossible, and as a temporary expedient, pending the completion of the purification plant, I resorted to the use of copper sulphate to keep the water supply free from disease-producing micro-organisms.
>
> My aim at first was to treat polluted tributaries and stagnant pools, which would drain into the river at the first rainfall, so as to render them harmless. The still water in deep pools, which upon analysis showed pollution, was also treated and at intervals, when the water in that part of the stream from which the city's supply was taken showed pollution, the treatment was applied directly to the water at the intake. At no time as the water enters the intake was it subjected to a treatment stronger than 1 part in 1,500,000. By carefully testing and treating the water of polluted tributaries and stagnant pools, it was seldom necessary to treat the river directly.
>
> Previously to the treatment of the water with copper sulphate only upon rare occasions was the water free from colon bacilli, but after the treatment was begun, from the 19th day of August to the 30th day of December, daily tests showed that the water was free of colon bacilli. During the heavy rainfall in the latter part of December, samples were taken from the hydrant tap at regular intervals of two hours both day and night. Notwithstanding the months of dry weather which pre-

> ceded the rainfall, the colon bacilli were present for a period not longer than sixteen hours.
>
> The treatment, which was begun and continued without the knowledge of the city authorities, was ordered stopped on January 5, 1905, after the daily papers published glaring accounts of the dangers attendant upon such treatment. To allay the fears of the people, five employees of the health department took daily for thirty days three-tenths of a grain of copper sulphate without any signs of discomfort or symptoms whatever.
>
> During the month of August there were reported to the health office 52 cases of typhoid fever; September, 16 cases; October, 16 cases; November, 8 cases; December, 17 cases, only 4 of which used city water; January, 1905, 91 cases; February, 376 cases.
>
> In January, 1905, not until the 14th was a single case reported that could be attributed to the use of the city water. On that day 3 were reported; on the 16th, 3; on the 18th, 3; on the 20th, 1; on the 21st, 3; on the 23d, 3; on the 24th, 14. From this date on the cases have averaged over 10 each day. No copper sulphate has been used since January 5, 1905.

The following tabulation of the data contained in the above report will perhaps show the results of the work more clearly:

Statement of typhoid cases reported in Columbus, Ohio, showing relation to use and nonuse of copper in the water supply.

	Month.	Typhoid cases reported.
No copper used	June	24
Do	July	33
Copper used after 19th	August	52
Copper used	September	16
Do	October	16
Do	November	8
Do	December	[a]4
Copper discontinued after 5th	January	91
No copper used	February	376
Do	To March 27	279

[a] 17 cases were reported, but only 4 were users of city water.

In connection with the results obtained at Columbus should be mentioned the treatment of the water supply at Albuquerque, N. Mex. This was reported upon by John Weinzirl, city chemist, as follows:

> I desire to inform you that we used your copper sulphate treatment in the reservoir of our city water supply this summer with good results. This reservoir was full of algæ, and the water-supply company could not clear it before certain improvements in their plant were installed. The flavor of the water was rank; but two treatments made a great improvement, though the water was rendered cloudy by the partly decomposed organisms. We applied the treatment late in July and in August. During October we had a small epidemic of typhoid, perhaps 50 cases; the water supply was again treated with copper sulphate, and within three weeks the epidemic ended.
>
> I might add that during the first treatment the bacterial content of the water fell to one-fourth the original number.

STERILIZATION OF WATER BY MEANS OF METALLIC COPPER.

The effect of metallic copper upon *Bacillus typhi* in water is of considerable importance. For small amounts of water it has been found convenient and desirable in many cases to guard against bacterial contamination by employing copper tanks, and where frequent boiling can not be resorted to the use of copper may be regarded as the only possible safeguard. In some cases this may not be absolute, for our experiments upon water from various places and the experiments of other investigators show that the chemical constitution of the water under consideration is of the greatest importance. Water that contains a very large amount of matter in suspension is perhaps the most difficult to sterilize. Under these conditions twenty-four to forty-eight hours at room temperature would probably be necessary for complete sterilization through the agency of metallic copper tanks; on the other hand, metallic copper in water containing a large amount of organic acid, or free acid of any sort, would destroy all typhoid bacilli in two or three hours at the most. Complete sterilization is a standard to which even the best filters seldom attain, and under the most unfavorable conditions the reduction in the number of bacteria in water exposed to the action of metallic copper for twelve hours will be approximately as great as in a filtered water. The copper must be kept clean, not, as is popularly supposed, to protect the consumer from copper poisoning, but because it is possible for the metal to become so coated with foreign substances that there is no longer any contact of copper and water, and hence no antiseptic action.

An interesting corroborative fact is the antiseptic property of copper coins. Lately considerable work has been done on this problem by the department of health of the city of New York,[a] and, as was to be expected, it was found that copper and nickel coins smeared with cultures of pathogenic bacteria, such as *Bacillus diphtheriae*, were completely sterile in a few hours, and that the same was true to a less degree of silver coins.

In a recent article, Dr. Henry Kraemer reviews the applicability of the germicidal power of copper to drinking water, and his results with the Philadelphia water show that standing four hours in the presence of copper foil completely destroyed both *Bacillus typhi* and *Bacillus coli*.

Doctor Kraemer's conclusions are quoted below:[b]

> In filtration processes it is generally understood that both typhoid and colon organisms are the first to be eliminated, and without waiting to make a systematic study of the organisms which persist as well as those which are killed in the copper treatment of water, I thought it well to test the method by using water containing these organisms alone. As results depend in some measure upon the method used, I will try to outline my method before giving my results.
>
> 1. Water under three different conditions was employed: (*a*) Distilled water which was prepared from tap water by first treating it with potassium permanganate and then distilling it two or three times by means of apparatus constructed entirely of

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[a] Report of Dr. Wm. H. Park, March 1, 1904.

[b] Henry Kraemer. The Efficiency of Copper Foil in Destroying Typhoid and Colon Bacilli in Water. American Medicine, February 18, 1905, Vol. IX, No. 7, p. 275.

glass; (*b*) filtered tap water, prepared by means of a Berkefeld filter attached to a copper spigot; (*c*) tap water, collected after being allowed to run through a copper spigot for five minutes. All of these were sterilized in an autoclave at 110° for thirty minutes.

2. The cultures of typhoid and colon which were used were pure cultures developed in bouillon for eighteen hours to twenty-four hours.

I may say that every single experiment which we have conducted * * * shows that copper foil is exceeding toxic to colon and typhoid bacilli, particularly the latter.

It will be seen by consulting the tables that in the filtered water, to which no copper foil had been added, the typhoid organisms did not grow and multiply as was the case with the tap water and distilled water, although there was a larger number of organisms to begin with. This also applies in a measure to the colon bacilli, with which there is a very marked inhibiting action in those growing in the filtered water.

At first I was inclined to attribute this diminution in the number of the organisms to minute traces of copper in the flasks, but subsequent experiments showed that this was not the case. I am, therefore, inclined to attribute these rather anomalous results to the presence of extremely small quantities of copper dissolved by the water in its necessarily slow passage through the copper spigot to which the filter was attached. This is a phase of the problem to which I am devoting my attention at present, as it certainly opens up an interesting side of this subject.

Even granting the efficiency of the boiling of water for domestic purposes, I believe that the copper-treated water is more natural and more healthful, inasmuch as the various inorganic constituents, particularly the salts of calcium and magnesium, are in a more soluble and assimilable condition, being furthermore less concentrated, at the same time the natural gases of the water being retained.

From the experiments thus far conducted the following conclusions may be drawn:

1. The intestinal bacteria, like colon and typhoid, are completely destroyed by placing clean copper foil in the water containing them.

2. The effects of colloidal copper and copper sulphate in the purification of drinking water are in a quantitative sense much like those of filtration, only the organisms are completely destroyed.

3. Pending the introduction of the copper treatment of water on a large scale the householder may avail himself of a method for the purification of drinking water by the use of strips of copper foil about 3½ inches square to each quart of water, this being allowed to stand over night, or from six to eight hours, at the ordinary temperature, and then the water drawn off or the copper foil removed.

Doctor Pennington, of Philadelphia, has reported[a] results of the board of health laboratory, showing complete sterilization of infected tap water within fifteen minutes by means of copper foil.

Rideal and Baines[b] have carried on some experiments concerning the germicidal effect of copper. Evidently they added too much of the culture to be tested to the treated water. The high concentrations required according to their tables to produce complete sterility can be explained only by the presence of considerable amounts of albuminoid matter, and under these circumstances the condition is comparable to sterilizing sewage rather than sterilizing drinking water.

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[a] At a meeting of the Washington Academy of Sciences, January, 1905.

[b] S. Rideal and E. Baines. The Suggested Use of Copper Drinking Vessels as a Prophylactic against Waterborne Typhoid. Journal of the Sanitary Institute, XXV, 1904.

Their experiments with metallic copper, though too few to be themselves at all conclusive, are entirely in accord with the results of the Laboratory of Plant Physiology as formerly published.

COPPER IN THE DISPOSAL OF SEWAGE.

In connection with the sterilization of water by means of copper the possibility of using this metal in the sanitary disposal of sewage should be mentioned. This is well described by Rideal,[a] from whom we quote:

> The soluble salts of copper have a distinctly poisonous action on bacteria. They coagulate albumen and combine with most of the organic acids present to form nonputrescible salts. They absorb sulphureted hydrogen, ammonia, and compound ammonias, and therefore combine with "ptomaines." In fact, copper salts rank next to mercury in power as antiseptics.
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> * * * * * * *
>
> Kroncke[b] contended that, for sewage treatment, compounds having a great affinity for sulphur should yield the best results. He has experimented with cuprous chloride as being a salt which fulfills this condition, is readily prepared, very easily removed from solutions, and becomes much less poisonous when oxidized. He used the following method for the purification of water: Cuprous chlorid amounting to one twenty-thousandth of the liquid to be treated, and ferrous sulphate (as far as possible free from ferric) to the extent of one fifty-thousandth, are mixed with the water. After six hours one one hundred-thousandth part of lime is added, and agitated for one hour. After settling for one and a half hours, and filtration through sand, the water, which originally contained 40,000 to 50,000 organisms per cubic centimeter, was found to be completely sterilized, clear, almost colorless, and free from iron and copper. The sand filter can be used a long time without cleansing. Schumburg[c] reports that a water treated with cuprous chlorid solution and then with lime was free from germs after six hours.

COPPER SUPPLEMENTING THE USE OF FILTERS.

It appears from the examination of a considerable number of filters in this country that the officials in charge of municipal waterworks are not justified in assuming that filtration is the absolute guarantee against a disease-laden water that it is popularly supposed to be. The number of unavoidable accidents which are known to occur in properly managed filters, to say nothing of the willful and sometimes criminal methods resorted to in order to bring the supply of water up to the daily demand, are factors which are not generally considered by the public. The mere fact that filters are installed seems to warrant neglect of the source of the water, and as a mistake or an accident usually can not be detected by the public until the death rate increases markedly, filtration as administered in a considerable number of cases has resulted in a condition more dangerous than if no filter existed. The sooner that it becomes generally known that any sort of filtration is a most delicate process, depending upon skilled manipulation for maximum efficiency, the better it will be both for filtration and the consumer of water. That it is not an unheard of practice to force considerably larger quantities of water through a sand filter than it can possibly free from disease germs (even resorting to spading over the sand to hasten the flow) ought to be understood by all those using such water. The direct pumping of polluted river water into the filtered water for the purpose of making up the daily supply has been resorted to, and the occurrence of breaks in storage basins, conduits, etc., has more than once afforded opportunities for the dangerous contamination of the filtered water.

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[a] Rideal. Disinfection and the Preservation of Food, New York, 1903; pp. 156, 157.
[b] Jour. für Gasbeleucht, XXXVI, 513.
[c] Chem. Centr., 1900, II, 203.

At the present time the only known method of immediately rendering a contaminated water supply safe and keeping it so until the source of pollution is removed seems to be the use of copper. This treatment is not designed to supplant efficient filtration, however, and should never be expected to take its place. The use of copper for removing a temporary contamination is necessarily a remedy and should be used as such. As much care is demanded of the sanitary engineer or biologist in determining the necessity for treatment and the proper quantity to be used as is demanded of a doctor in determining the dose for a sick person. A pure water should not be treated, just as a well person should not take medicine.

The existing methods of sewage disposal and water purification are particularly unfortunate. To deliberately contaminate a water and then try to purify it seems ridiculous, yet this is precisely what is now being done in a number of communities. The ultimate solution of the problem of water supply must depend upon proper sewage disposal as well as the proper care and policing of the watersheds and wells. Until this revolution of methods shall have taken place, the makeshifts—filtration, and treating with copper—are the only remedies applicable on a large scale.

COPPER TREATMENT AND FILTRATION AT ANDERSON, IND.

By the invitation of Mr. C. Arthur Brown, sanitary engineer of the American Steel and Wire Company, acting at the time as the representative of the Jewel Filtration Company, and through the courtesy of the officials of Anderson, Ind., the Laboratory of Plant Physiology was enabled to undertake a series of experiments upon the effect of copper treatment of water in connection with mechanical filtration. The filter plant had been recently completed, and these experiments were carried on at the time of the preliminary testing of the efficiency of the filters.[a] The water supply at Anderson, Ind., offered exceptional opportunities for demonstrating the efficiency of copper in removing intestinal bacteria. The water is drawn from the White River, into which the city of Muncie empties its entire sewage. There are no falls or rapids in the 25 miles separating these two cities, and during the entire four weeks of the test conducted on the use of copper in connection with filtration the river was icebound, making a closed conduit for the diluted sewage from Muncie and the smaller towns still farther up the river. The water was very high in albuminoid and free ammonia, and exceptionally high in chlorin, due to the salt water from the gas field above Muncie. The turbidity was very low and the color slight. Fortunately for the thorough testing of the value of copper, the filters, owing to some structural defects, were unable to effect a high percentage reduction of bacteria at this time. The number of bacteria in the river ranged from 13,000 to 155,000 per cubic centimeter at irregular intervals during the four weeks' test, usually remaining above 50,000. The number of bacteria in the filtered water varied between 15,000 and 400 per cubic centimeter, usually remaining above 3,000.

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[a] Professor Burrage, professor of sanitary science at Purdue University, was retained by the city of Anderson as its representative, as well as Dr. S. C. Norris, city chemist and bacteriologist. Mr. Brown acted as the representative of the filtration company.

For ten days, February 2–11, 1904, alum was used as a coagulant, but for water of this character it seemed impossible to get a proper coagulation with 1, 2, or 3 grains of alum per gallon, either with or without the addition of lime. *Bacillus coli* was always present in the river water and usually in the filtered water, and was identified by gas formation, reduction of neutral red, proportion of carbon dioxid, growth on milk, potato, gelatin, litmus agar, and formation of indol. On February 11, instead of aluminum sulphate, iron sulphate containing 1 per cent of copper sulphate was introduced in quantities of 1½ grains per gallon of water.[a] Lime was added, 2 grains per gallon. The treatment was continued four days, and during that time only once was there any indication of the presence of *B. coli* in fermentation tubes inoculated with 1 c. c. samples of filtered water, and this occurred immediately after a leak developed in the air pipe of the washing system that allowed unfiltered water to pass into the pipes. On the 15th of February, the amount of iron sulphate containing 1 per cent of copper sulphate was raised to 4½ grains per gallon. This quantity was found to be too great, and at midnight the amount of the coagulant was reduced to 2¼ grains.[b] The valve controlling the iron solution caught on this change and for nearly an hour no iron or copper was applied to the raw water. This allowed polluted water to reach the clear well, and at the next washing the filters were again contaminated, and samples from two of them developed typical *Bacillus coli*. The following five days

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[a] 0.015 grain copper sulphate per gallon—approximately 1 part of copper sulphate to 4,000,000 parts of water.

[b] 0.0225 grain copper sulphate per gallon—approximately 1 part of copper sulphate to 2,500,000 parts of water.

B. coli developed but once, and this was immediately following the reappearance of the leak in the air pipe.

Iron sulphate containing one-half per cent copper sulphate was now applied at the rate of 1.5 grains[a] per gallon; *Bacillus coli* was eliminated during the two days that this mixture was used. Iron sulphate containing only one-fourth per cent copper sulphate[b] was substituted during one day. This amount was insufficient to eradicate completely the *B. coli*, and two of the filter samples contained this organism.

Pure iron sulphate was then used at the rate of 3 grains per gallon, and *Bacillus coli* developed from samples of each filter. Iron sulphate containing 1 per cent copper sulphate was substituted for the greater part of the pure iron salt, and in the following samples no *B. coli* developed in the filtered water.

From the preceding experiments there seems to be no doubt that the filtering of polluted water of this character through the layer of coagulum of iron and copper which forms on the filter bed brings the bacteria borne in the water into contact with the precipitated copper for a sufficient length of time to destroy *Bacillus coli*, and as *Bacillus typhi* is still more sensitive to the action of copper it too must necessarily be removed from the filtered water.

The last samples of the test have been omitted from previous discussion, as the point illustrated by them is of an entirely separate character. Shortly before these samples were taken, ten gallons of a bouillon culture of *Bacillus prodigiosus* were introduced into the feed pipe of the filters, and the following and last samples all showed *Bacillus coli* present. This emphasizes the fact brought out in a former bulletin[c] that the toxicity of copper sulphate is greatly reduced if the amount of organic and albuminoid matter is greatly increased. A proper comprehension of the constitution of a water is therefore necessary for successfully treating to remove bacteria, just as it is desirable for treating to remove algæ.

It should be reiterated that the results of investigators with reference to the germicidal action of copper in bouillon, milk, or solid media are not comparable to results upon the toxic action of copper in water of ordinary purity. Nor can results obtained with unknown organisms, nor results obtained with *Bacillus anthracis*, *Bacillus tetanus*, and such spore-forming resistant bacteria be compared with results obtained with *Bacillus typhi* and *Microspira comma*.

One of the objections to the use of copper sulphate in water supplies has been that there was a chance of appreciable amounts of copper reaching the consumer. Considering the harmlessness of copper, this is a theoretical rather than a practical objection, and is answered in the present instance. The copper is all precipitated and the insoluble coagulum of iron and copper is caught upon the filters.

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[a] 0.0075 grain copper sulphate per gallon—approximately 1 part of copper sulphate to 8,000,000 parts of water.

[b] 0.00375 grain copper sulphate per gallon—approximately 1 part of copper sulphate to 15,000,000 parts of water.

[c] Bulletin No. 64, Bureau of Plant Industry, p. 29.

Table showing the presence or absence of Bacillus coli per cubic centimeter in samples from various sources at Anderson, Ind.

Chemicals applied (in grains per gallon) and time of sampling.		River.	Settling basin.	Filter No. 1.	Filter No. 2.	Filter No. 3.	Filter No. 4.	Tap.
1 grain alum:								
February 2	a. m.	+	+	+	+	+	+	+
	p. m.	+	+	+	+	+	+	+
February 3	a. m.	+	+	+	+	+	+	+
	p. m.	+	+	−	+	+	−	+
2 grains alum: February 4, a. m.		+	+	−	−	+	−	+
3 grains alum:								
February 4, p. m.		+	+	−	+	+	−	−
February 5	a. m.	+	+	−	−	−	−	+
	p. m.	+	+	−	+	+	+	+
February 6	a. m.	+	+	+	+	−	+	+
	p. m.	+	+	+	+	+	+	−
February 7	a. m.	+	+	+	+	+	+	+
	p. m.	+	+	+	+	+	−	+
February 8	a. m.	+	+	−	−	−	−	+
	p. m.	+	+	−	−	−	+	−
February 9, a. m.		+	+	−	+	+	−	−
2 grains alum:								
February 9, p. m.		+	+	−	+	+	+	......
February 10, a. m.		+	+	+	+	+	+	+
1½ grains alum, 2 grains lime:								
February 10, p. m.		+	+	+	−	+	+	+
February 11, a. m.		+	+	−	−	−	−	+
1½ grains iron sulphate, 0.015 grain copper sulphate, 2 grains lime:								
February 11, p. m.		+	−	−	−	−	−	+
February 12, a. m.		+	+	−	−	[a] +	−	......
1½ grains iron sulphate, 0.015 grain copper sulphate, 1½ grains lime:								
February 12, p. m.		+	−	−	−	−	−	−
February 13	a. m.	+	−	−	−	......	−	−
	p. m.	+	+	−	−	−	−	+
February 14, p. m.		+	+	−	−	−	−	−
February 15	a. m.	+	−	−	−	−	−	−
	p. m.	+	−	−	−	−	−	−
2¼ grains iron sulphate, 0.0225 grain copper sulphate, 1½, 1, and ¾ grains lime: [b]								
February 16	a. m.	+	+	−	−	[a] +	−	−
	p. m.	+	+	−	[b] +	−	[b] +	+
February 17	a. m.	+	+	−	−	−	−	+
	p. m.	+	+	−	−	......	−	−
February 18, p. m.		−	+	−	−	−	−	−
1 grain iron sulphate, 0.0075 grain copper sulphate, ¾, and 1 grain lime:								
February 19	a. m.	−	−	−	−	−	−	−
	p. m.	+	+	−	−	−	−	−
February 20	a. m.	+	+	+	−	−	−	−
	p. m.	+	+	−	−	−	−	−
1 grain iron sulphate, 0.00375 grain copper sulphate, 1 grain lime:								
February 21	a. m.	+	−	−	−	......	−	−
	p. m.	+	+	+	+	......	+	−
3 grains iron sulphate, 1 grain lime:								
February 22	a. m.	+	+	+	−	......	+	+
	p. m.	+	+	+	+	+	+	+
3 grains iron sulphate, 0.03 grain copper sulphate: February 23, a. m.		+	+	−	−	−	−	......

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[a] The presence of *Bacillus coli* in filter No. 3 on February 12 and 16 is due to a leak which developed in the air wash pipe, allowing unfiltered water to pass into the pipes.

[b] The amount of iron sulphate was raised to 4½ grains at 6 p. m. on February 15, but this was too much for the filters to accommodate, and at midnight the amount was reduced to 2¼ grains; at this time the valve stuck and for some time no iron or copper was introduced into the water. This allowed contaminated water to pass the filters, and at the next washing the contaminated water from the clear well again contaminated the filters, and near enough the time of sampling to show *Bacillus coli* in two of the samples.

OBJECTIONS TO THE USE OF COPPER SULPHATE.

During the past year several articles have appeared, some of a more or less alarmist nature, containing adverse criticism of the copper sulphate method of treating reservoirs. In some instances the efficiency of the method is questioned; in others, objection has apparently originated in the prejudice which obtains in some quarters, due to the supposed ill effects upon the human system of the absorption of small quantities of copper.

In view of the year's experience in practical applications of the treatment, nothing need be said further in behalf of its efficiency.

The existence of conditions which might make treatment with copper undesirable is not overlooked, but, so far as is known, these are peculiar to certain localities and of a nature which presents difficulty from the engineering rather than the hygienic standpoint.

The appearance of resistant forms after the removal of the polluting organism by means of dilute solutions of copper sulphate has been mentioned by engineers as possibly producing a worse condition than that previously existing in the water. Certainly such an objection would have been worthy of careful consideration had it been raised before an opportunity had occurred to test the efficiency of copper sulphate as an algicide. Experience with all water supplies treated, however, proves that such a difficulty is not to be feared and that the destruction of the algæ is so rapid as to prevent the evolution of similarly contaminating forms resistant to copper.

The case which has been under observation for the longest time is that at Ben, Va., where, in January, 1902, cress beds were treated for the eradication of Spirogyra. Conditions were such as to be unusually favorable for the development of the algæ, and certainly if a form resistant to copper could be produced under natural conditions it would have appeared here. After the first treatment was made several subsequent applications of copper in diminishing quantities were resorted to, but the algæ, instead of being more difficult to eradicate, were easier and easier to kill, and in a recent letter Mr. Moomaw, proprietor of the cress beds, states that the algæ have been completely destroyed and no other form has appeared.

OPINIONS OF TOXICOLOGISTS UPON THE EFFECT OF COPPER SULPHATE.

In a few instances objection has been made to the use of copper sulphate, even in the minute quantities shown to be efficient for the purpose of sterilizing water. Some authors have held that anything which would destroy algæ and bacteria would likewise kill man,[a] while others have maintained that nothing is known of the effect of the infinitesimal dose which might be administered.[a] The opinions of eminent toxicologists seem fully to answer both the violent objections and the conservative doubts as to the possible injurious effect upon the human system of copper thus used.

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[a] Medical Bulletin, October, 1904.

The literature relating to the harmlessness of copper is so voluminous as to make it impossible even to refer to most of it, but a few of the more recent articles upon the subject are quoted in order that the authorities who may desire to improve the character of the water supply under their control may have the benefit of the experiments of those who have investigated the effect of this metal upon man and other animals.

Dr. Henry Kraemer, in an article in the American Journal of Pharmacy, December, 1904, wrote as follows:

> The toxic influence of even very minute quantities of colloidal copper and of copper sulphate on certain micro-organisms having been pretty well established, the only other question of importance that arises in connection with their use for the purification of water supplies containing pathogenic organisms and algæ is the one as to their effects on man. Inasmuch as this phase of the question is dependent upon physicians and pharmacologists for its elucidation, the editor of this journal has asked several members of the medical profession to discuss it.
>
> It is to the credit of the medical profession that while some of those asked to contribute to this discussion have more or less positive convictions on the subject, others have been frank to say that their observations and experience in this line of investigation have not been sufficient to warrant them in giving an opinion at this time. One pharmacologist writes: "As I understand the purification method, the quantities of copper remaining in solution are so extremely small that they would scarcely be harmful."
>
> Another eminent pharmacologist writes that when he was consulted by a city official to give an opinion as to whether 1 part of copper in 1,000,000 parts of water would be harmful, he replied that, "Assuming for purposes of argument that the copper remains in solution and is not deposited or rendered insoluble, this small quantity could not be harmful to our citizens, even if they drank such water for a few days, since our ordinary food, as bread, meat, etc., all contain from 2 to 3 parts in the million. Some tissues, like the liver, contain as high as 30 parts in the million."
>
> Up to the time of going to press replies were also received from Doctor Hare, professor of materia medica and therapeutics in the Jefferson Medical College, and from Doctor Holland, dean and professor of medical chemistry and toxicology in Jefferson Medical College. Their replies are as follows:
>
> MY DEAR PROFESSOR KRAEMER: In reply to your note let me state that small doses of copper exercise, so far as is known, a stimulant effect upon nutritional processes. I do not think that we have any information in regard to the infinitesimal quantities which are present in water when treated by the copper method, but it is incredible that they could exercise any deleterious influence. Certainly the improbable deleterious influence of infinitesimal quantities of copper when compared to the certain evil influence of micro-organisms amounts to nothing.
>
> Very truly yours,
>
> H. A. HARE.
>
> PHILADELPHIA, *November 14, 1904.*

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[a] American Medicine, November 12, 1904.

Mr. Henry Kraemer,
Editor of American Journal of Pharmacy.

Dear Sir: In this paper on purification of water by copper I think that Doctor Moore shows conclusively that water supplies can be freed of pathogenic bacteria and algæ promptly, cheaply, and efficiently by that means. The question remaining to be answered is, Can this purification be done with entire safety to those drinking the water?

Until comparatively recent times it has been thought that the slow introduction of minute doses of copper was injurious to the tissues by causing such pathological changes as are known to be due to certain other metallic poisons, such as lead, arsenic, and mercury. But Bernatzic has proven that to produce toxic phenomena with copper salts it must be given freely and intentionally, and even then the subject spontaneously recovers when the administration ceases. When a student of medicine I was made aware of the harmlessness of copper sulphate in small doses. Quinine was very expensive then, and in the dispensary practice of a malarious region some cheaper substitute was needed. Hundreds of cases were treated with a combination of the sulphates of cinchonine, iron, and copper. About one-eighth of a grain of sulphate of copper was given several times daily in this routine prescription for a tonic and antiperiodic.

I do not remember that any untoward symptoms developed, though they were not unexpected, as the books then taught that copper salts were irritants. So they are, but only in doses much larger than one-eighth of a grain. We saw no cumulative effects. Lehmann and his pupils found that a man could take 1 to 2 grains of copper as sulphate and acetate daily in peas and beans divided into two meals without effect.

The highest sanitary authorities appointed to investigate this matter have reported that "copper in the amounts found in canned goods is not capable of injury to health."

Metallic copper is not a poison. Surgeons have used copper wire for suturing wounds without noticing local irritation; children swallow copper pennies daily without injury to the digestive tract. As copper is present in almost all our food it is not surprising to learn that each of us takes daily about one milligram of copper, and that it is found regularly in our tissues. I see no reason to fear copper if the amounts never exceed the small proportion stated by Doctor Moore as entirely adequate for the purification of water supplies.

J. W. Holland.

Philadelphia, *November 15, 1904.*

Dr. A. R. Cushney, in his Treatise on Pharmacology and Therapeutics,[a] writes:

Small quantities of copper may be taken for indefinite periods without any symptoms being induced, so that so far as man is concerned the general action of copper is unknown. * * * On the other hand, copper is a deadly poison to several of the lower plants. Thus, traces of copper added to the water in which they live, destroy some of the simpler algæ, and Naegeli asserts that 1 part of copper in 1,000,000,000 parts of water is sufficient to kill these plants. * * * Locke found that the traces of copper contained in water distilled in copper vessels were sufficient to destroy Tubifex (one of the annelid worms) and tadpoles, while Bucholtz states that the development of bacteria is stopped by a solution of copper sulphate under 1 per cent in strength. Copper thus seems to have a very powerful poisonous action on certain living forms and to be harmless to others, and the subject deserves further investigation. It is possible that it may prove to act prejudicially to some human parasites, and it is certainly less dangerous to man than many other remedies used as parasiticides and disinfectants.

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[a] Pharmacology and Therapeutics, New York, 1899, p. 159.

Dr. R. A. Witthaus[a] has published a similar opinion:

> The opinion, formerly universal among toxicologists, that all the compounds of copper are poisonous has been much modified by later researches. Certain of the copper compounds, such as sulphate, having a tendency to combine with protein and other animal substances, produce symptoms of irritation by their direct local action when brought in contact with the gastric or intestinal mucous membrane. One of the characteristic symptoms of such irritation is the vomiting of a greenish matter, which develops a blue color upon the addition of NH_4HO.
>
> Cases are not wanting in which severe illness, and even death, has followed the use of food which has been in contact with imperfectly tinned copper vessels. Cases in which nervous and other symptoms referable to a truly poisonous action have occurred. As, however, it has also been shown that nonirritant, pure copper compounds may be taken in considerable doses with impunity, it appears at least probable that the poisonous action attributed to copper is due to other substances. The tin and solder used in the manufacture of copper utensils contain lead, and in some cases of so-called copper poisoning the symptoms have been such as are as consistent with lead poisoning as with copper poisoning. Copper is also notoriously liable to contamination with arsenic, and it is by no means improbable that compounds of that element are the active poisonous agents in some cases of supposed copper intoxication. Nor is it improbable that articles of food allowed to remain exposed to air in copper vessels should undergo those peculiar changes which result in the formation of poisonous substances, such as the sausage or cheese poisons, or the ptomaines.

MEDICINAL USE OF COPPER.

The probable medical value of copper in treating typhoid and related diseases was suggested in the former bulletin. Salts of this metal have been used for many years in treating dysentery, and in one instance at least diphtheria has been treated with copper sulphate with remarkable success.

The use of copper in treating typhoid fever was reported upon by Dr. Lucien F. Salomon, of New Orleans.[b] We quote from recent letters from Doctor Salomon, as follows:

> Two years ago I published the results of my experience claiming to *cure* typhoid fever with the arsenite of copper. Subsequent experience in its use confirms the claim then made. I use the word "*cure*" because within seventy-two hours after beginning its administration in a given case, what was a severe case of typhoid becomes converted into a simple benign fever, and the patient recovers in ten or twelve days. (May 10, 1904.)
>
> I have clinical records of a number of cases treated with arsenite of copper since the publication of my article, all of which show the same good result. (June 11, 1904.)

As has been shown in Bulletin No. 64 of the Bureau of Plant Industry, the toxic effect of copper upon cholera germs is even greater than upon typhoid bacilli.

The following account of some practical experience with the effect of copper upon cholera bears out this laboratory's experiments, and there are numerous instances in this country where the beneficial effect of some form of copper upon cholera epidemics has been observed:

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[a] The Medical Students' Manual of Chemistry, New York, 1902, p. 207.

[b] The published article appeared in the New Orleans Medical and Surgical Journal for June, 1902.

Dr. Arthur de Noé Walker, in a pamphlet entitled "The Prophylactic Power of Copper in Epidemic Cholera" (London, 1883[a]), wrote as follows:

> When the following facts receive the attention they deserve Asiatic cholera will cease to destroy mankind.
>
> In the year 1849, and again in 1851, Tuscany was ravaged by a severe epidemic of Asiatic cholera, and for the sixth time I had every opportunity of observing and studying this, perhaps, the most fatal disease of modern times. While noting down some of the observations published by Professor Betti on both epidemics, the following paragraphs were particularly remarked and transcribed:
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> > I believe I ought not to conclude the history of the epidemic of Asiatic cholera that afflicted the city of Prato and the adjacent country without saying a few words about a particular industry carried on in the vicinity of that city, and state the effects of the same on the workmen.
> >
> > It is well known that in the valley of the Bisenzio, distant only 4 miles from Prato, and precisely at a place called La Briglia, are the furnaces where the copper ore excavated from Mount Romboli is smelted. With the object of bringing to light the influence that process might have on the disease, I deemed it opportune to institute certain special investigations, and having interested the government authorities on the subject, the following intelligence was obtained:
> >
> > The workmen engaged at the smelting furnaces at La Briglia, in the valley of the Bisenzio, when the epidemic broke out in Prato and in the adjacent country, were 58, which number, added to the individuals composing their respective families living within a radius of about 3 miles from the furnaces, made up a total of 150 souls.
> >
> > Among all those individuals, not only no case of real Asiatic cholera, but not even a sporadic case, nor a case of cholerine, occurred.
> >
> > I was, moreover, assured that not one of them was affected by even the slight gastric and intestinal disturbance so common in those living in localities attacked by the deadly malady, although they—the workmen and their families—live in damp situations along the Bisenzian torrent. Their diet is that of all ordinary laborers.
>
> The value of this fact was, in my estimation, at once doubled by another, noted by Professor Betti. He states that the disease attacked, and in every instance proved fatal, to many living in the valley of the Bisenzio and in the neighborhood of the smelters' families, but that those so attacked and succumbed had, directly or indirectly, nothing whatever to do with the furnaces nor with any of the workmen employed in smelting the ore.
>
> I must here note, on evidence I have myself collected, that one workman, thoroughly inquinated and having his person and garments dusted over by a prophylactic agent, consequent, e. g., on a sufficiently long attendance at a smelting furnace, becomes an efficient means or vehicle whereby all the members of his household may become protected by that same agent. This was assumed the moment the professor's observations were read. Thus, conversely, an accoucheur, or a monthly nurse that has attended a case of puerperal fever, fatal or not, is liable to affect scores of other women. Some contagia frequently are, as is well known, conveyed by one healthy individual to many others; and it was simply inferred that if contagious matter can thus pass from one person to many, it was not at least unlikely that a prophylactic agent might likewise pass from one member to others of the same family.
>
> Observations I need not here detail have proved to me that the assumption entertained when Betti's observation was read is now no longer an hypothesis.[b]
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> Workmen engaged at smelting furnaces, or otherwise employed in working the metal, become thoroughly impregnated with the ore, which adheres all over the

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[a] Written twenty years previously. Published with a few additions in 1883.

[b] "On the Effects of Copper upon the System." Proceedings of the Clinical Society of London. Vol. 3.

common integument. An appreciable quantity may be easily obtained by burning some of the hair of men constantly engaged in smelting the ore.

After reading Professor Betti's observations every available means and opportunity was sought with the object of ascertaining whether the same immunity could be verified at other establishments where copper was worked in any sort of way. The result proved that not one person habitually engaged in working copper had been attacked by cholera, not even among those whose work simply consisted in polishing the metal.

The indefatigable Frenchman, Burq, has published a valuable work on the preventive and curative action of copper in epidemic cholera, in which he honestly and courageously quotes Hahnemann, proving that he followed in the steps of that extraordinary genius. But Burq, while still a medical student attending lectures, spared no expense, no pains, no trouble, in order to prove this most important fact. He allowed nothing to deter or to discourage him—not even the insults of the Academy of Science and Medicine nor the slights of some physicians holding important appointments under the French Government.

"One day," he says, "some private business led me to visit an important copper foundry in the Rue des Gravilliers. In the course of a casual conversation with one of the workmen I learned that they, as well as all the inhabitants of the establishment, numbering about 200, had, in 1832, and again in 1849, been exempt from cholera. The fact of such complete immunity, although it might have been due to a mere fortuitous exception, greatly surprised me, and I asked myself if metals might not have other properties especially antagonistic to cholera besides those I had discovered. Nevertheless, I soon began to lose sight of the fact, when a similar observation, with a sort of pertinacious tenacity, again presented itself to my notice, and notably in connection with other copper foundries situated in the same street, where from 400 to 500 workmen and others occupying the premises had, one and all, been absolutely free from the disease. This strange and all-important immunity could not, I reflected, be due to the healthiness of the district or to the exceptionally healthy state of the houses, all of which, without exception, were as poor as those generally selected for foundries of any kind. Neither could it be ascribed, as I have said, to the good hygienic condition of the inhabitants generally nor to the exceptionally low mortality of the neighboring habitations. It became, therefore, impossible for us to look upon this complete immunity simply as a coincidence, and from that moment I allowed myself no rest nor respite until I had proven without a shadow of a doubt this peculiar property of copper—a property I had hitherto based on a mere supposition. In order to obtain this important result, as I said in 1853, I gave myself up and devoted myself to pursue a vast inquiry, of which the following are the chief results:

"In Paris, I personally visited 400 workshops, and other places where metals are worked; from the most modest, where four, five, or ten workmen are employed, to extensive establishments, where the workmen may be counted by hundreds, as may be done at Messrs. Cail & Cave's establishment. I also visited the iron founderies in the suburbs of Saint Marceau and Saint Jacques, and the type foundry in the Rue Vangirard, the manufactories of Messrs. Lagoutte, Calla, Gouin, and Farcot. At Chapelle and Saint Ouen, the founderies of Messrs. Cail & Co.; at Chaillot and Grenelle; and the manufactory of castors in copper in the suburbs of Saint Antoine; and, finally, all the workers in bronze at Marais. I then put myself in communication with the presidents, treasurers, and secretaries of workmen's unions, and likewise questioned the workmen themselves at their homes or lodgings. Contemporaneously, I wrote to the proprietors, directors, and physicians of our chief manufactories, forges, wire makers, and metal beaters. To the mayors and magistrates of towns where, as at l'Aigle and Villedieu, the inhabitants are almost all occupied in working metals, requesting them to give me information regarding the course and progress the epidemic had taken and made in their respective localities. Not satisfied with having obtained accurate information regarding a vast number of persons, I communicated with the English, Swedish, and Russian ambassadors, with Professors Huss, of Stockholm; Montferrand, of St. Petersburg (director of the Siberian mines belonging to Prince Demidoff), who afforded me information respecting no less than 46,500 miners of both sexes. Finally, I obtained information from the chief and most extensive metallurgic establishments in Europe, the cutlers of Sheffield, the copper refiners in the principality of Wales; the boiler makers of Birmingham; the mines at Phalen of Linkepening, in Sweden; at Stolberg, at Silecia, and many others. And it was after a correspondence and inquiries of every kind, carried on for a period of five months, concerning a population of 200,000 souls, that we believed we had the right to address the Academy of Medicine and Sciences, in a memoir, concluding as follows:

"I. Complete immunity from cholera of the immense majority of all workmen whose calling necessitates their being habitually in contact with copper dust.

"II. Copper and its alloys, brass and bronze, permanently applied to large surfaces of the common integument, are a most precious preventive, which ought in no wise to be neglected and can cause no inconvenience. If these means leave something to be desired as a prophylactic, it will probably be found expedient to reduce the metal to an impalpable powder and to ingest a few pinches.

"III. In the treatment of cholera, copper, opportunely administered, whether in copper filing alone or in any other form which experience shall determine, affords the greatest probability of proving in the hands of the physician a powerful means of cure."

Doctor Clapton[a] describes the "habitual lassitude and giddiness" of some of the laborers engaged in copper works, and more violent symptoms in two cases. From his description all the laborers were evidently saturated with salts of the metal, yet disagreeable effects, even under such conditions, are undoubtedly rare. To quote more directly:

"On the whole, I may say that the workmen are a healthy set of men. They do not suffer from any definite diseases, as do the workers in lead, arsenic, and mercury.

"One very remarkable circumstance (of which I was first informed last year by Benham and Froude, Chandos street) was mentioned at each of the works, viz, the absolute freedom of the workmen from cholera or even choleraic diarrhea. During each of the great cholera outbreaks there were terrible ravages in one or other of their neighborhoods, but not one of these men was in the slightest degree affected.

"At all events, the immunity of this class of men from cholera is a remarkable and positive fact. I have for a long time made many inquiries in this matter, and can not as yet learn that a single case has occurred amongst them.

"It seems to me, therefore, that in seasons of cholera some form of taking it in small quantities as a prophylactic might be devised with the utmost benefit—perhaps the sulphate of copper; it is not in any way injurious, even if it should do no good. Doctor Elliotson related the case of a patient who had taken sulphate of copper daily for three years, for a particular complaint, without its having produced any constitutional effect.

"How is it that the effect of copper, even when inhaled for years, is comparatively so slight, and does not lead on to any special diseases? Probably, as I think, because the system can tolerate an excess of what is a natural constituent, however minute in quantity, infinitely better than it can the introduction of what is entirely foreign, such as lead, arsenic, and mercury; and in my opinion it has been clearly shown that copper is a natural constituent."

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[a] Edward Clapton, Clinical Society of London, Transactions, **3**:7 (1870).

CONCLUSION.

Experience has demonstrated the practical value of copper sulphate as an agent for the purification of contaminated water, and it is believed that most of the important conditions likely to obtain have been encountered and successfully dealt with. Unsuspected features may arise, however, and more complete information on the influence of the chemical constitution and temperature of the water and on the recurrence of polluting organisms is very much to be desired. It is therefore urged that water engineers, sanitary engineers, and others who may be interested keep accurate records of treatments made and report any unusual cases that may present themselves.

SUMMARY.

During the summer of 1904 over 50 reservoirs were successfully treated for the removal of algæ. From these results and from further experiments in the laboratory and elsewhere the following facts have been developed:

Much less copper is required to eradicate algæ from reservoirs than would be necessary to destroy algæ under laboratory conditions.

The effect of this metal upon fish is of considerable importance and requires more study.

The physical and chemical constitution of a water are factors to be considered in determining the quantity of copper sulphate to use in a water supply.

The elimination of polluting forms sometimes makes possible the development of other species, but so far these species have never been the cause of complaint.

As a result of the sudden destruction of great numbers of polluting algæ for a few days immediately after treatment of a water supply there is sometimes an increase in odor and taste.

The use of copper is an efficient emergency method for sterilizing water contaminated with the bacillus of typhoid fever.

Metallic copper offers a convenient and efficient means of sterilizing small amounts of water.

Copper may be useful in the proper disposal of sewage.

Copper is of great value as a supplement to filtration in case of accident or mismanagement.

Under certain conditions copper may be used to great advantage in connection with filtration.

There is no authentic record of fatal copper poisoning, and many of the best authorities do not consider copper a true poison; they hold that it is a natural constituent of the body, and in minute quantities has no effect upon man.

The suggested medicinal use of copper in cholera, typhoid, and related diseases seems important.

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